MONITORING, ASSESSING AND EVALUATING THE POLLINATOR SPECIES (HYMENOPTERA: APOIDEA) FOUND ON A NATIVE BRUSH SITE, A REVEGETATED SITE AND AN URBAN GARDEN

A Dissertation

by

CARRIE ANN CATE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2007

Major Subject: Entomology

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Approved by:

Chair of Committee,	S. Bradleigh Vinson
Committee Members,	Marvin Harris
	Stephan L. Hatch
	Steven G. Whisenant
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ABSTRACT

Monitoring, Assessing and Evaluating the Pollinator Species
(Hymenoptera: Apoidea) Found on a Native Brush Site,
a Revegetated Site and an Urban Garden. (May 2007)

Carrie Ann Cate, B. S., West Texas State University;
M. S., Midwestern State University
Chair of Advisory Committee: Dr. S. Bradleigh Vinson

This research presents the findings of a pollinator diversity study that took place at three study sites. Although variation in pollinator diversity occurred between the three sites, fewer pollinators than expected were recorded from the La Joya Tract (revegetated site). Numerous genera and species were recorded from the Havana Tract (native site) as well as the Valley Nature Center (urban garden). In contrast, the La Joya Tract had a comparatively depauperate pollinator fauna.

The numbers of pollinator genera and species recorded from the three study sites were decreased in comparison to the total number of genera and species recorded from Hidalgo County. Hidalgo County has 35 known genera and 75 species of bees documented to date. About 40% of the genera and 23% of the species recorded from Hidalgo County were recorded from the Havana Tract in this study, while a mere 8.5% of the genera and 4% of the species were reported from the La Joya Tract and 34% of the genera and 16% of the species were reported from the Valley Nature Center.

Although the vascular plant species identified from these study sites were

diverse, the floral rewards they provided yielded an insight as to what was going on in terms of pollinator diversity. Plants may yield nectar or pollen floral rewards or both in some cases to pollinators. The current study provides evidence that revegetation of land with plants that primarily provide nectar rewards will result in fewer observed bee taxa than from land revegetated with plants that provide a mix of nectar and pollen floral rewards.

DEDICATION

Johnathan Nathan Cate

beloved child

ACKNOWLEDGMENTS

I wish to thank my committee for their understanding, encouragement, input and endurance throughout this project. I would like to thank Dr. Marvin Harris, Dr. Stephan Hatch and Dr. Steven Whisenant for all of their support and knowledge. Above all, I owe a great deal of thanks to my chairman, Dr. S. Bradleigh Vinson. He always believed in me and kept pushing me to see this project come to fruition. Many thanks for all his time and efforts spent on my behalf. This gave me the strength and perseverance to press forward.

One professor who had a lot of influence over my career choice of Entomology was Dr. Horace Burke. He provided plenty of challenges while encouraging me throughout every aspect of taxonomy. My sincere thanks are extended to Dr. Burke.

Thanks are given to my good friends, Allen and Susan Dean, who have helped me in so many ways throughout the years. They edited the manuscript, provided technical support, map scans and moral support throughout this entire endeavor.

The Texas A&M University Entomology Collection, curated by Ed Riley, provided much needed background information on the genera and species of bees anticipated to be encountered at the onset of this work. Thanks to the Entomology Department for such excellent resources.

Thanks are given to Dr. Frank Eishen with the USDA Honey Bee Lab facility in Weslaco for allowing access and usage of their high powered microscope to determine preliminary bee identifications.

Dr. Jack Neff with the Central Texas Melittological Institute in Austin performed the final bee species identifications. He also provided the county records for bee species found in Hidalgo County. He gave of his time and expertise freely and I am indebted to him.

POPAL, the pollen listserv, provided an excellent forum for much needed information as well as useful references and resources. Thanks to all who responded to my questions and requests.

The director of the Valley Nature Center, Martin Hagne, gave me full access to the nature park (urban garden) during the period of study. Many thanks are given to him and the staff at the VNC.

United States Fish and Wildlife Service (USFWS) cooperated completely with this project by allowing two of their tracts to be used in this study. Ken Merritt encouraged biological research to be performed on refuge lands. Dave Blankinship helped shape this research with his biological knowledge. Jeff Rupert toured me through a number of prospective sites and gave of his time. Chris Best provided much knowledge with regards to the revegetation efforts and data of the La Joya tract. Thanks to USFWS for being such a great partner in this endeavor.

Dr. Norman Horner and Dr. Rodney Cate of Midwestern State University must be given credit for instilling in me the need to know more and to go the distance. Thanks to them for all they gave to me.

Thanks to my good friend and colleague, Dr. Frank Benton, who encouraged me to finish this work. There were numerous stumbling blocks and Dr. Benton was always quick to provide moral support when I felt like giving up. He also gave suggestions and edited my earlier drafts.

My family has always been a source of great strength and support. Many thanks are extended to them just for being there.

Last but not least, I would not be finishing this project but for the grace of God and his strength.

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CHAPTER I

INTRODUCTION

Insect pollination of flowers was discovered over 200 years ago in Europe, but its economic importance was not realized until the 20th century. The U.S. Department of Agriculture (USDA) (1979) estimated that at least 150 major crops relied on wild pollinators, which include solitary and social species of bees. Some plants are completely dependent on insect pollination for pollen transfer (Gill, 1989) and at least 800 cultivated plant species have been reported to rely on bees for pollination (Buchmann and Nabhan, 1996). Economically, the value of pollinators in the United States has been estimated to be between $182 million and $3 billion in 1982 prices (Wooten, 1987). Worldwide, it is estimated that 67 % of all flowering plants depend on insects for pollination (Tepedino, 1979). The most common of these insect pollinators are bees (Proctor et al., 1996).

Throughout the world, 25,000 species of bees have been described that are known pollinators. Within the United States it is estimated that there are 4,000-5,000 species of bees which achieve their greatest abundance and diversity in deserts and savannas, but tend to decline in number in tropical regions (Buchmann and Nabhan, 1996). Of the seven families of bees that are included in the superfamily Apoidea, five have been recorded from south Texas: Colletidae, Andrenidae, Halictidae, Megachilidae

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This dissertation follows the style of the Journal of the Kansas Entomological Society.

and Apidae (TAMU Entomology Department Collection, 1999; Neff, personal communication, 2004).

Pollen adheres to the hairs of insects or other pollinators that are foraging on blossoms in search of nectar, and as the pollinator moves from flower to flower, some of this pollen is dislodged, thus effecting pollination. Bees in particular effect the cross-pollination of receptive plants as they gather both pollen and nectar. However, pollen gatherers are more efficient pollinators than bees that only gather nectar, because they are more likely to carry greater amount of pollen on their bodies and more likely to transfer pollen to the stigmas of flowers (Kevan, 2001).

In addition, bees are morphologically and behaviorally adapted to collect and transport pollen. For example, Megachilids carry pollen on stiff hairs on the ventral abdomen, Andrenids collect pollen on hairy tarsi, *Apis* (such as the honeybees, bumblebees and a number of solitary species) carry pollen in specialized structures, the corbiculae, formed from the outer surfaces of the hind tibiae. In addition, pollen adheres readily to the branched hairs common to all bees. Bees are also more versatile pollinators than other insects as a result of several behavioral adaptations. Honey bees, *Apis mellifera*, are long-lived and less effected by low temperatures and light levels than many other insects, and may forage all year long or as long as it is warm (Faegri and van der Pijl, 1971). In addition, honeybees are able to perceive the form, color, size, pattern, taste and smell of a flower, and have developed the means of communicating the location of a floral food source to other members of the hive. Recruitment of workers and conditioning of bees to flowers of a certain color or species, allows honeybees to efficiently exploit floral patches (Kapil, 1986). Because of this, honey bees are less efficient in transferring pollen to widely spread and rarer plant species though many solitary species tend to be specialists (Frankie, 2004).

Solitary bee populations have been steadily decreasing over the past 100 years mostly as a result of insecticide use and habitat loss (Torchio, 1991). Studies in Costa Rica conducted from 1972 to 1996 indicate decreases of as much as 90% in the bee fauna have taken place in some communities (Frankie et al., 1993). Habitat fragmentation plays a key role in the reproductive strategies of plant populations, which, in turn, causes changes in pollinator populations (Buchmann and Nabhan, 1996). Populations of oligotrophic bees (those visiting only a few related host plants) are more likely to be decreased than those of polytrophic bees (species visiting many plant species), because of their dependence on a narrow range of floral hosts (Kearns and Inouye, 1993).

In agricultural conditions, the brief outbursts of flowering that occur in orchards and fields provide an overabundance of resources for a short period of time. Although this resource may be sufficient to feed one generation of nonsocial bees, there may be too few alternate floral hosts in the area to support a long lived species or this population all year round (Vinson et.al., 1993). In addition, whether ground nesting or tree hole nesting, many solitary bees may have difficulty surviving because of the elimination of nesting sites in cleared fields. There has been little research into the impact of habitat loss and fragmentation on pollinators, and little attempt made to protect pollinator populations from further agricultural or ecological disturbances (Allen-Wardell, 1998).

The ecological community and the environmental movement have supported the idea of habitat restoration. The goal of habitat restoration is to create a stable climax community with a persistent mixture of species that is capable of being self-sustained. Land that has been cleared of its native vegetation or fragmented may be managed by the ecological process of succession to hasten revegetation. Stable communities are unique, each being composed of characteristic soils, water resources, plants and animals. A restored ecosystem should be as productive as its native ecosystem counterpart and environmental or land characteristics should be carefully examined to place human activities in the landscape with the least amount of impact. The four most important components of a whole landscape management plan are: 1) maintaining a few large areas of natural vegetation, 2) maintaining vegetative corridors along waterways, 3) maintaining connectivity to allow the movement of key species among large patches and 4) maintaining heterogenous parcels of land (green belts) in urban areas (Meffe et al., 2002).

The objective of the present study was to monitor bee populations in three different habitats in the Lower Rio Grande Valley National Wildlife Refuge. By observing bees in a native brush site (Havana Tract) versus a revegetated landscape (La Joya Tract) versus an urban garden site (Valley Nature Center), one expects to determine whether there were differences in the species diversity and abundance in these different habitats. This information might provide a measure of the effectiveness of habitat revegetation to the USFWS. Observations of bee species would also yield valuable information regarding host plant preferences and attractiveness of various plants to bees, and would determine whether a given species was a generalist (polytrophic) or specialist (oligotrophic).

A diversity of pollinators would suggest a diversity of plants. A diversity of plants would suggest a diversity of herbivores and their predators and parasites.

CHAPTER II

REVIEW OF THE LITERATURE

Pollinators and Pollination Ecology – Significance and Importance

Bees are efficacious pollinators as a result of several morphological adaptations that enhance their ability to collect and transport pollen. Because pollen is a rich protein source (16-30% by composition), many bees collect and transport large quantities. Solitary species provision cells in which an egg is deposited with the pollen serving as a resource for the developing bee larvae. Some semi-social bees collect pollen in their crops and regurgitate it to the larvae. Social bees store a lot of pollen in special cells that are then used as a source of protein for larval rearing (Roubik, 1992; Michener, 2000).

Bees are also more versatile pollinators than other insects as a result of several behavioral adaptations. Honey bees, *Apis mellifera*, live in colonies consisting of a single queen, several thousand sterile females and several hundred males in a hive consisting of parallel wax combs. Because honeybees are long-lived and store resources, they are less affected by breaks in resources. They also are less affected by the seasonality (temperature, humidity and daylight) than many other insects, thus these bees may forage over a long period of time (Faegri and van der Pijl, 1971). In addition, honeybees have developed the means of communicating the location of a floral food source to other members of the hive. Recruitment of workers and conditioning of bees to flowers of a certain color or species, allows honeybees to efficiently exploit floral patches (Kapil, 1986). Many studies indicate that honey bees, *Apis mellifera*, exhibit considerable fidelity to the same area of flowering plants (Butler et al., 1943; Singh, 1950; Weaver, 1957; Gary et al., 1977). However, this can be a problem for plant reproduction. Many out crossing plants require the movement of pollinators over long distances (Frankie et al., 1993). Also, honey bees are not good at transporting some kinds of pollen (Vaissiere and Vinson, 1994). Thus, other species have been used in recent years (Williams and Thomson, 2003). Bumblebees of the genus *Bombus* exhibit a time-memory that allows them to remember the daily rhythm of a blossom; they have been observed to hover around a blossom, waiting until it opens (Heinrich, 1979). Euglossine and Anthophorini bees display trapline behavioral strategies whereby widely dispersed, long blooming tropical shrubs and trees are pollinated by these bees flying between them (Real, 1983). Some bees, e.g. *Centris*, exhibit territorial behavior and may cause others to leave a specific plant to forage elsewhere (Frankie et al., 1974).

Bees typically live in habitats consisting of rewarding patches of floral resources with suitable nest sites within range of each other. Although all bees have broad universal tastes for nectar, many solitary species have fixed species specific requirements for pollen from a narrow range of hosts and a few are known as oil collectors (Vogel, 1981). The emergence of these oligotrophic species of bees must coincide with the floral bloom of their plant hosts on a seasonal or annual basis. In contrast, polytrophic bees, including honeybees, have more universal tastes for a wide variety of floral species. They are often multivoltine or long-lived bees that outlast the bloom period of any specific floral host. The flight range of these species from nesting sites must include various floral hosts that will bloom at different times throughout the year. For example, *Centris* requires nectar and depends on a series of resources to get through the nesting season (Vinson et. al., 1993). Also some species are specialists and are abundant when their plant is flowering (Michener, 2000).

There is wide variety among bee nesting sites as discussed in (Michener, 2000). These include small openings in trees, tree cavities, hollow plant stems, abandoned rodent burrows, or in soil having the appropriate slope, texture, moisture and vegetative cover and at the appropriate depth. Solitary bees often nest in soil or in rotting logs. For example, the alkali bee, *Nomia melanderi* nests in soil that is sub-irrigated, while nesting sites of *Megachile rotundata* include burrows, nail holes and fissures in logs. Bumblebees, which are considered to be at the evolutionary midpoint between solitary and social bees, nest in a variety of dry, sheltered locations. Some species prefer to enter nests through underground tunnels, while others nest on the surface of the ground under grass or plants. Other species of bumblebees nest in empty bird's nests, bales of hay, old upholstered furniture, compost piles and under concrete walks, thatched roofs and the floors of outbuildings. Wild or escaped swarms of honeybees usually nest in hollow trees (Michener, 2000).

However, pollinator populations have been steadily decreasing as a result of insecticide use and habitat loss (Torchio, 1991; Frankie et al., 1993). In the past few decades, the populations of wild bees, including solitary and bumble bees, have proven to be inadequate to sufficiently pollinate crops and other flowering vegetation. In fact, many farmers will rent commercial beehives to ensure that adequate pollination occurs (The Texas Honey Bee Research and Management Plan, 1998).   Habitat loss and fragmentation result when native habitats are converted into farms, highways, houses, malls, office complexes, city parks and industrial parks. As a result, bee populations are reduced because of a decrease in the number of suitable nesting sites and plant hosts. In agricultural situations, bees may have difficulty surviving because of the elimination of nesting sites but this issue is complex. For example, in agricultural fields, *Augochlora,* a halictid, did poorly, as a result of removal of the rotting tree stumps and logs that they nest in. Another halictid, *Dialictus,* however, is a ground-nester and was able to find small remnants suitable for survival (Michener, 1974).

Reductions in plant populations resulting from habitat loss, pollution and chronic herbicide usage also effect abundance and diversity of pollinator species. Populations of oligotrophic bees may be decreased, because of their dependence on a narrow range of floral hosts. Polytrophic or polylectic bees, that accept multiple floral hosts, are more likely to adapt to habitat loss and fragmentation. In a large-scale monoculture that occurs in agricultural situations, native bee populations may be reduced. At the same time outbursts of flowering that occur in orchards and fields provide an overabundance of resources fails to support native bees over the long period. At the same time pollinators of the flowers suffer as the native bee populations are too low to be effective. So honey bees are brought in. This creates competition for the native bees which are further declined. A continuous sequence of flowering plants is of prime importance to sustain bee populations. Loss of habitat and pollinator populations causes a vicious circle of reduction of plant populations, because most plants depend on pollinators for propagation and pollinators depend on plants for nectar and pollen (Caron, 2001).

Bee Taxa : Overview (Condensed from Michener, 2000)

Of the Superfamily Apoidea, there are seven families of bees of which five are represented from south Texas (Appendix A).

The family Colletidae is composed of five diverse subfamilies that are often referred to as plasterer or yellow-faced bees. Species richness and abundance is greatest in temperate parts of Australia and South America. All of which are solitary, although some nest in aggregations. These bees commonly nest in burrows in the soil, pithy stems and rotting wood. Three of the five subfamilies occur in Texas.

The first is: *Colletes* which occurs in temperate and tropical regions of all the continents except Australia. Most *Colletes* are ground nesting bees. Secondly, *Hylaeus*, which is a group of small bees, that has a worldwide distribution, occurring on all continents except Antarctica. *Hylaeus* visit a wide variety of flowers from which they collect pollen and nectar that are stored in their crops. Many of these bees nest in dead woody stems. Lastly there is *Ptiloglossa* which is found in tropical America to southern Texas and Arizona.

The family Andrenidae consists of four extremely diverse subfamilies. Andrenids can be distinguished from other bees by the presence of two subantennal sutures below each antenna. Andrenids occur throughout all the continents except Australia, but they are most abundant in the temperate areas of North and South America. All Andrenids nest in burrows in the soil. *Andrena* occurs from the southern Western Hemisphere to Panama, in Africa, in Asia and throughout most of the world. There are more than 1,300 species within this genus. The species are highly variable in coloration, but have a similar morphologically. The genus *Perdita* has the greatest species abundance and diversity in the southwestern United States and northern Mexico, with a limited distribution in the Atlantic or Pacific coastal areas. There have been over four hundred species described to date.

The family Halictidae has a worldwide distribution, primarily occurring in temperate regions. Commonly known as sweat bees, halictids nest in burrows in the soil and occasionally in rotting wood. Some halictids are cleptoparasites, and many are tan or black and metallic. *Agapostemon* is an extremely common bee taxon, occurring in North America from coast to coast, and less commonly in South America. There are 43 described species of *Agapostemon*. The large genus of *Augochloropsis* occurs in a range from South America to Arizona to eastern North America. These moderately sized bees are either a metallic green or blue, or a non-metallic black color. These bees nest in the soil. *Augochlora* occur in the United States and throughout South America. They are black, bright green or blue bees of medium size. *Halictus* has a worldwide distribution. This genus is very diverse and has many species. They are usually ground nesters. *Lasioglossum* is an enormous genus containing morphologically similar species of bees. These bees may be solitary or social.

The family Megachilidae is composed of two large subfamilies that are found throughout most of the world, and are often referred to as leaf-cutter bees. These long-tongued bees are among the most easily distinguished families of bees in the world. The large genus *Megachile* occurs throughout most of the world. These bees are morphologically distinct and behaviorally diverse. Some *Megachile* are polyphyletic and visit a wide range of flowers for pollen while others are more species specific. The genus *Coelioxys* is found on all continents except Australia. Species are black, although the legs and other parts are sometimes partly red. They are cleptoparasites primarily of *Megachile*. *Lithurgus* are robust bees and nest usually in old decaying wood. This genus has a wide distribution in the drier regions of the tropics and in temperate areas.

The family Apidae consists of three diverse subfamilies. Nomadinae is composed of cleptoparasites and superficially resemble wasps. They lack pollen collecting structures. Xylocopinae are very diverse with respect to size and appearance. Some are large and robust while others are slender and small. Apinae are the most eusocial of the corbiculate Apidae. These long-tongued bees vary in habit from solitary to social, from nest provisioners to parasites and cleptoparasites. They nest in pre-existing cavities, in the soil or in open areas. *Xylocopa*, or carpenter bees, have a worldwide distribution. These large, robust bees are often confused with bumblebees. They excavate branching tunnels in wood for their nesting sites. The genus *Ceratina* has a worldwide distribution except for a more limited distribution in Australia. The species in the genus *Ceratina* are small, slender bees that vary in color from black to metallic green, and nest in dead stems or hollow twigs. The genus *Exomalopsis* is found only in the New World, mainly in neo-tropical areas. These minute to moderate sized bees form communal nesting sites that have been recorded from depths greater than five meters. Subsequent generations build on the original nest to extend it. *Diadasia* is a large genus being most speciose in North and South America. They nest in shallow burrows in large aggregations with small turrets at the entrance to their burrows. *Bombus*, or bumblebees, are found throughout most of the world, although they are more abundant in cool temperate regions. They are medium to large in size and are extremely hairy; they nest as an eusocial colony each year in the spring. *Apis*, the honeybee, is worldwide in distribution. Its original range was altered by human activity, but it is native to Africa, Europe and Western Asia. It is a small to medium-sized bee and is moderately hairy. Nests are often found in cavities in hollow trees or in the ground. (TAMU Entomology Department Collection, 1999; Michener, 2000).

Restoration Ecology and Land Mosaics

Restoration ecology studies the interaction among organisms and their environment when an attempt is made to restore an ecosystem to something near its native condition. Ecosystem restoration consists of two stages. In the first stage, the ecosystem is studied to determine whether problems exist such as incomplete utilization of resources including water, nutrients and light, or the presence of invasive (introduced or native) species. In the second stage steps are taken to correct these problems. The role of certain components important to the study of ecological processes is often better understood upon lands that have undergone fragmentation and destruction rather than on natural ecosystems. The linkages and associations of species and importance of one or more key species are often best revealed by their absence (Ewel, 1987).

Landscapes that are natural or result from the activities of man may be viewed as a patchwork or mosaic of interrelated pieces. The patch-corridor-matrix model was developed from the realization that landscape mosaics are composed of only three types of spatial elements: the patch, the corridor and the matrix, or background landscape. These elements may apply to a variety of ecosystems, community types, successional stages or land uses (Forman, 1998).

A patch is a relatively wide, homogenous area that differs from its surroundings. A disturbance patch is the result of an alteration or disturbance in a small area, while a remnant patch, in contrast, is a small vegetative area that escaped the disturbance. The rock or soil types present in the area define an environmental patch and a regenerated patch is an area of re-growth on a previously disturbed site. Introduced patches are areas that have either been re-vegetated or have structures erected upon them as a result of human activities. Patch shape has an influence over the productiveness of the landscape. An elongated patch is less effective in conserving internal resources than a round patch, however, elongated plots are more efficient than circular plots for sampling purposes. Boundaries or ecotones best define landscape patches because they represent spatial or temporal discontinuity in structural and functional properties (Forman and Moore, 1992; Wiens, 1992; Crow and Gustafson, 1997).

Corridors are elongated, narrow strips of land that permeate the land. Nature creates corridors in the form of streams, ridges and animal trails. Humans create corridors in the form of walking trails, power lines and roads. Corridors have five major functions in the landscape: habitat, conduit, filter (barrier), source and sink. As habitats, they provide sanctuary for flora and fauna; as conduits, they provide channels for species to move along. When the corridor prevents or inhibits species from crossing between patches it acts as a filter or barrier. A corridor that functions as a source supplies other areas with species, one that functions as a sink absorbs species. Corridors provide a means of dispersal to a wide variety of species traveling from one protected area to another (Forman, 1998).

The matrix is defined as the background landscape. If one element type covers over half the total area of the landscape background or is more extensive than another, then it should be considered to be the matrix. If two element types are similar in total area, their connectivity throughout the landscape should determine which element is the matrix.

Fragmentation of the landscape may be defined as the process of breaking up a large habitat area into smaller parcels and in the process form widely and unevenly separated remnants. Perforation is the process of making holes in the habitat or landscape. Dissection of the land occurs when roads are built through, and penetrate the habitat. Shrinkage is a decrease in the size of the habitat, and attrition is the disappearance of a patch or corridor. Perforation and dissection occur at the beginning of landscape alteration, while fragmentation and shrinkage are secondary effects followed by attrition (Forman, 1998).

Land that has been cleared of its native vegetation or fragmented may be managed by the ecological process of succession to hasten revegetation. The laws of succession as proposed by Clements (1916) consist of six stages. Nudation is the process by which a disturbance leaves only residuals. Residuals include the biotic and abiotic components of an ecosystem, and are key factors in ecosystem regeneration. New species are re-introduced to the ecosystem by migration and these species must become established in order to survive. Biological interactions of species during the successional cycle will also determine the role of the organism in the community. Competition between species is a negative interaction, because both are competing for the same resource (Forman, 1998). Over time, organisms may change their own environment and alter the community to the point where their progeny will not endure. Ultimately, a self-sustaining climax community results from the process of succession (MacMahon, 1987).

The goal of habitat restoration is to create a dynamic equilibrium, a climax community, with a persistent mixture of species that is capable of being self-sustaining over time. Successful re-vegetation should lead to the reconstitution of the entire interactive community. Stable communities are unique, each being composed of characteristic soils, water resources, plants and animals. In successful restorations, invasion by exotic species is minimized, because resources such as water, light and nutrients are efficiently used and retained in the ecosystem. In addition, a restored ecosystem should be as productive as its uncleared land counterpart. Restorations may vary from huge plantings of one or a few species to small strips or patches of land with many vegetative species, and environmental or land characteristics are carefully examined to place human activities in the landscape with the least amount of impact.

Land restorations must be extensively planned and managed. Landscape and ecological planning focus on major linear features within the landscape such as natural corridors along roads; these are especially significant for species movement and protection. The four most important components of a whole landscape management plan are: 1) maintaining a few large areas of natural vegetation, 2) maintaining vegetative corridors along waterways, 3) maintaining connectivity to allow the movement of key species among large patches and 4) maintaining heterogenous parcels of land (green belts) in urban areas (Meffe et al., 2002).

The preservation of biodiversity on our planet requires an ecosystem rather than a species by species approach. There are many threatened or endangered species on the brink of extinction as a result of natural range limitations or limitations based on habitat degradation (destroyed or fragmented). The measurement of invertebrate diversity within an area, although it is often overlooked, is a good indicator of overall diversity for the entire ecosystem (Franklin, 1993). However, millions of species inhabit the earth, and we lack the time and financial resources to focus on saving critical habitat for each species. Different strategies are required for the preservation and conservation of an ecosystem rather than an individual species (Cairns, 1987).

There are three recognized strategies concerning habitat ecology. The first is referred to as reservation ecology. This is the dominant strategy of conservation biology. This is best explained simply as: save the natural habitats. The second is restoration ecology. Whereby developed land is returned into natural habitats but less land is available for restoration than reservation. The third strategy is reconciliation ecology. This involves finding environmentally sound ways to continue using the land for ourselves in conjunction with reservation and restoration. Reconciliation ecology lacks recognition and organization. Its main goal is to keep alive plant and animal species along with us; not in captivity but in the wild. Mankind was to protect all of the species and not cause their extinction (Rosenzweig, 2003).

Biotic Communities of South Texas

The four county region referred to as the Rio Grande Valley consists of eleven biotic communities that range from Falcon Dam on the western edge of Starr County to Boca Chica Beach on the gulf in Cameron County. These communities consist of: Coastal Brushland Potholes, Loma/Tidal Flats, Sabal Palm Forest, Mid-Valley Riparian Woodland, Mid-Delta Thorn Forest, Woodland Potholes, Upland Thorn Scrub, Barretal, Upper Valley Flood Forest, Ramaderos and ChihuahuanThorn Forest (U.S. Fish and Wildlife Service (USFWS), 1997). The Lower Rio Grande National Wildlife Refuge is an important region for wildlife conservation research. Although there has not been an evaluation of the invertebrate communities occurring in revegetated versus native brush habitat, monitoring of invertebrate populations is essential to establish better land management practices and to determine the baseline diversity of insects and their host plants. Effective restoration is dependent upon insect-plant interactions. Monitoring bee populations in native brush versus a restored landscape versus an urban garden site would enable the USFWS to better measure the effectiveness of restoration methods. Areas are being revegetated and it is good to create as natural a habitat as possible. The present day approaches should be leading up to revegetation with the idea of habitat restoration. The question: is the revegetation effort resulting in restoring a diverse habitat or is it more of a community planting? Here I propose to evaluate to what degree the revegetated site reflects the natural habitat. I propose to determine the bee diversity on these areas. I also propose to evaluate the bee diversity in an urban garden and discern if a diversity of flowering plants can increase bee diversity. Observations of bee species should also yield valuable information regarding host plant preferences and attractiveness of various plants to bees, and would determine whether a given species was a generalist (polytrophic) or specialist (oligotrophic).

CHAPTER III

MATERIALS AND METHODS

The Lower Rio Grande Valley National Wildlife Refuge (LRGV NWR) is primarily a river corridor system of approximately 90,000 acres distributed over 100 different tracts of land in Starr, Willacy, Hidalgo and Cameron Counties. Only 5% of the native south Texas habitat remains, while 95% has been converted for agricultural or urban use (USFWS, 1997). All of the native habitats of the Lower Rio Grande Valley have been stated as being endangered and declining (Noss and Scott, 1997). Currently, the USFWS revegetates approximately 1000 acres (405 hectares) of land per year that had been previously cleared for agricultural purposes. They use approximately 30 – 40 species of native plant seedlings for revegetation purposes.

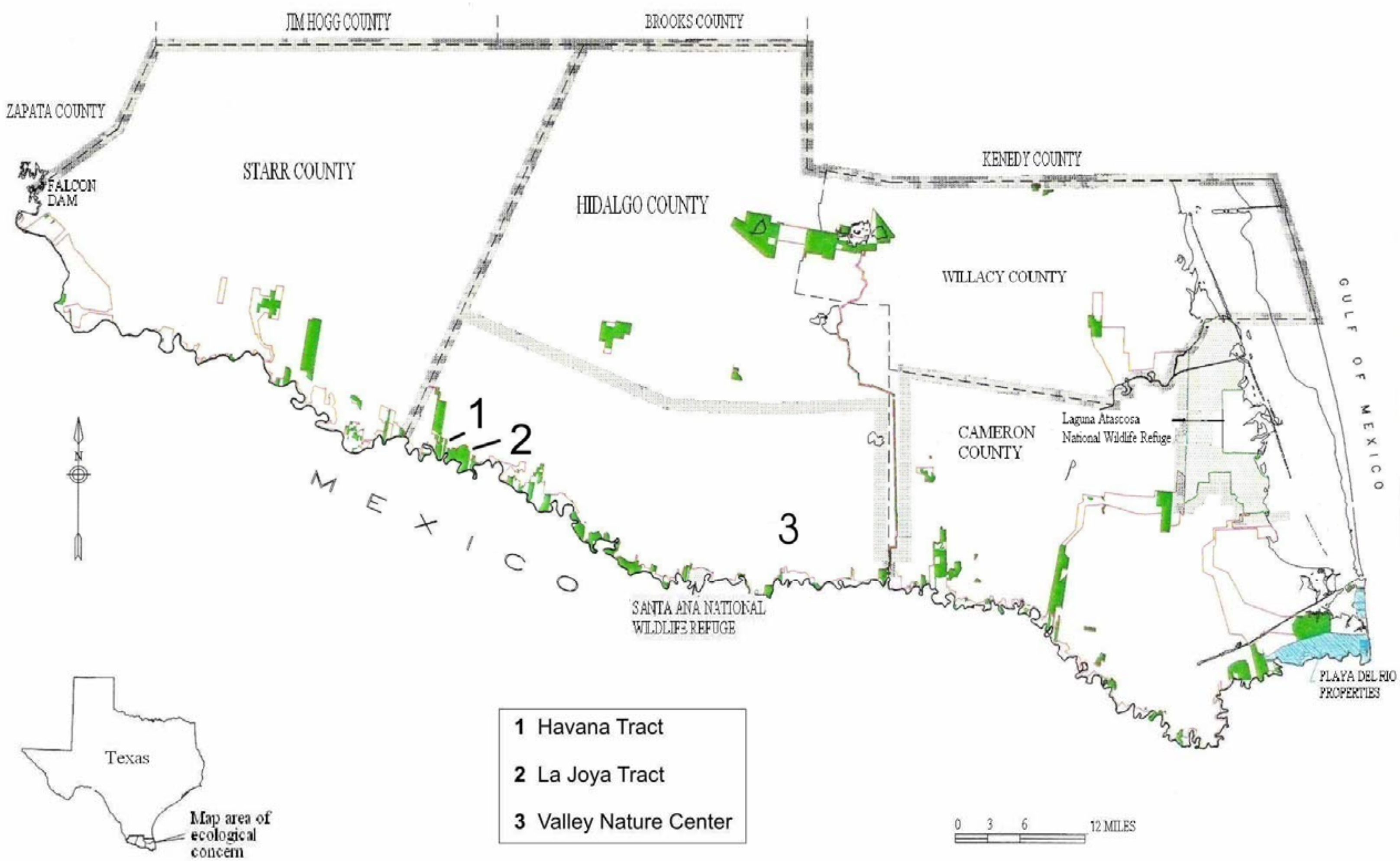

Figure 1. Overview Map of the South Texas Study Sites

Three study sites were chosen for comparison of bee populations. This study was a traditional field collection and observational study. Observations were conducted over a period of three years for the USFWS tracts and two years for the Valley Nature Center site (Fig. 1). It was performed to compare the pollinators with the seasonality of the plant blooms and site types.

The first site, the Havana Tract of the Lower Rio Grande Valley National Wildlife Refuge, served as a study site representing an uncleared, native brush tract of land. The Havana Tract represents reservation ecology. This site is approximately 50 acres in size, and consisted of an Upland Thorn Scrub biotic community within the Rio Grande Ecosystem. It is the most widespread habitat type in the Tamaulipan Biotic Province and occurs on higher and drier sites to the north and west of the Rio Grande

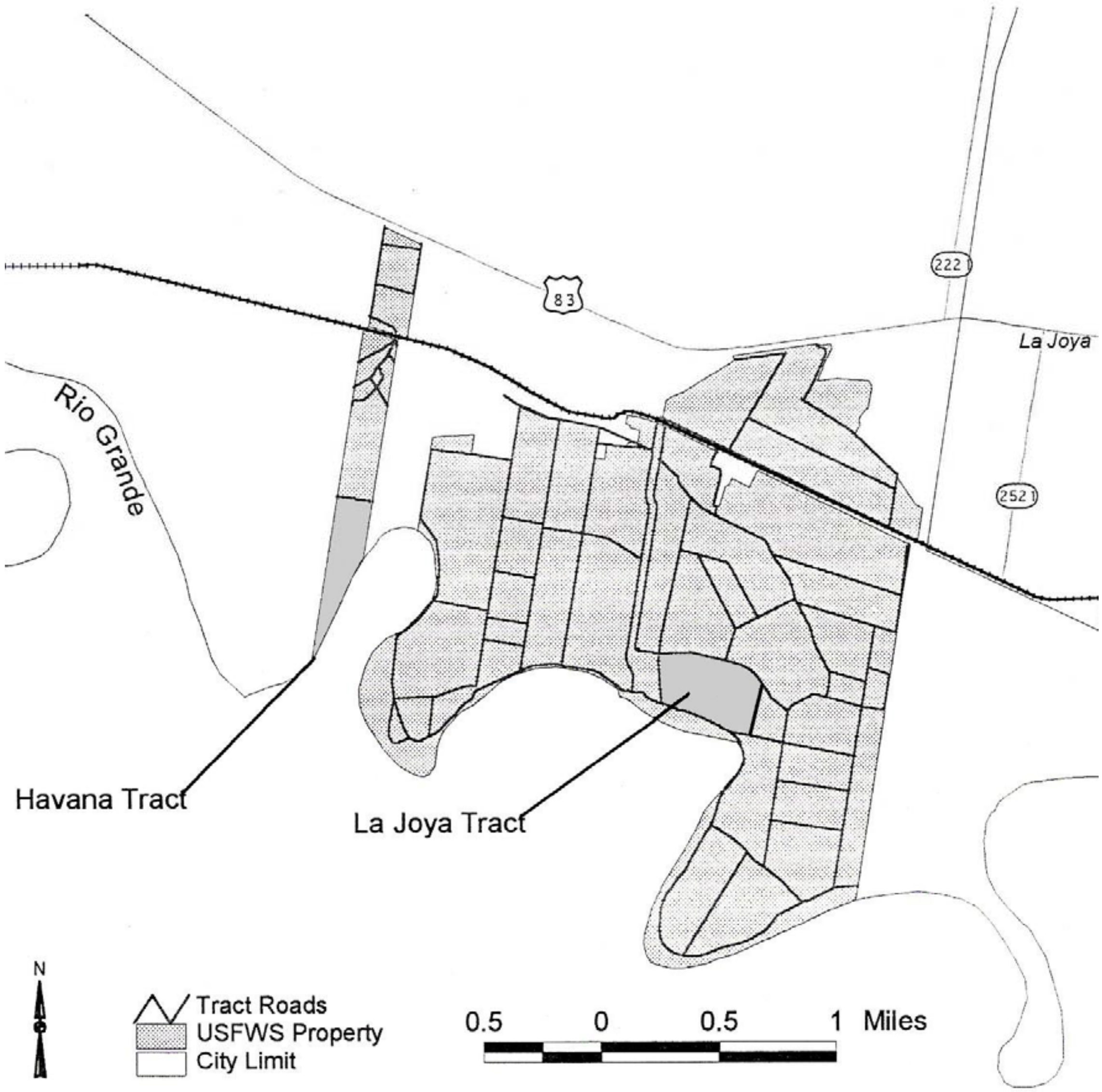

Figure 2A. Location Map of the Havana and La Joya Tracts

Delta. Typical woody plants are anacahuita (*Cordia boissieri*), cenizo (*Leucophylum frutescens*) and palo verde (*Cercidium texanum*). The Rio Grande lies to the south while agricultural fields border the Havana tract on two other sides; agricultural fields also abound across the Rio Grande in Mexico. This makes it quite difficult for ground nesting species to be productive.

The second site, the La Joya Tract of the Lower Rio Grande Valley National Wildlife Refuge, served as a study site representing a revegetated tract of land. The La Joya Tract serves as the secondary strategy: restoration ecology. The revegetated plot is approximately 52 acres, and the Rio Grande lies to the south and borders the La Joya tract. It was initially revegetated in June 1992 and has been in the process of being revegetated by USFWS for over ten years. Other revegetated plots of land within the La

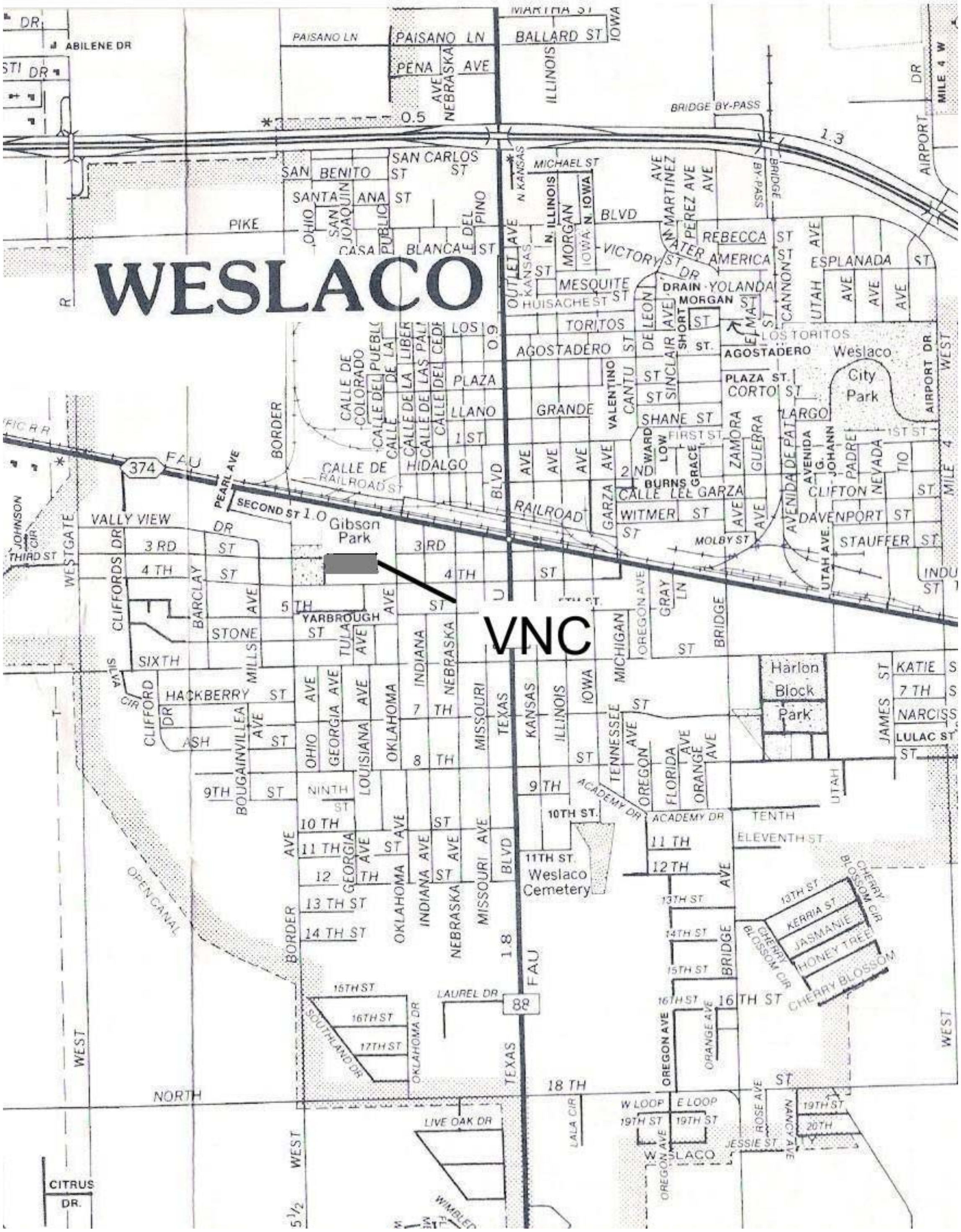

Figure 2B. Location Map of the Valley Nature Center (VNC)

Joya tract were replanted throughout the years and surround the revegetated study site on three sides. Much habitat disturbance and fragmentation has occurred all around this site as well as on adjacent properties. The patch work effect may be influencing the productiveness of the bee guilds. The Havana and La Joya tracts of the Lower Rio Grande Valley National Wildlife Refuge were used as study sites for a period of three years, 1999 – 2002 (Fig. 2A). Both sites had the same climactic influences as a result of their close proximity to each other, being approximately 0.5 miles (0.8 kilometers) apart.

In 2001, because of continuing drought conditions, a third site, the Valley Nature Center located in Hidalgo County in Weslaco, Texas was added (Fig. 2B). The Valley Nature Center is a prime example of reconciliation ecology.

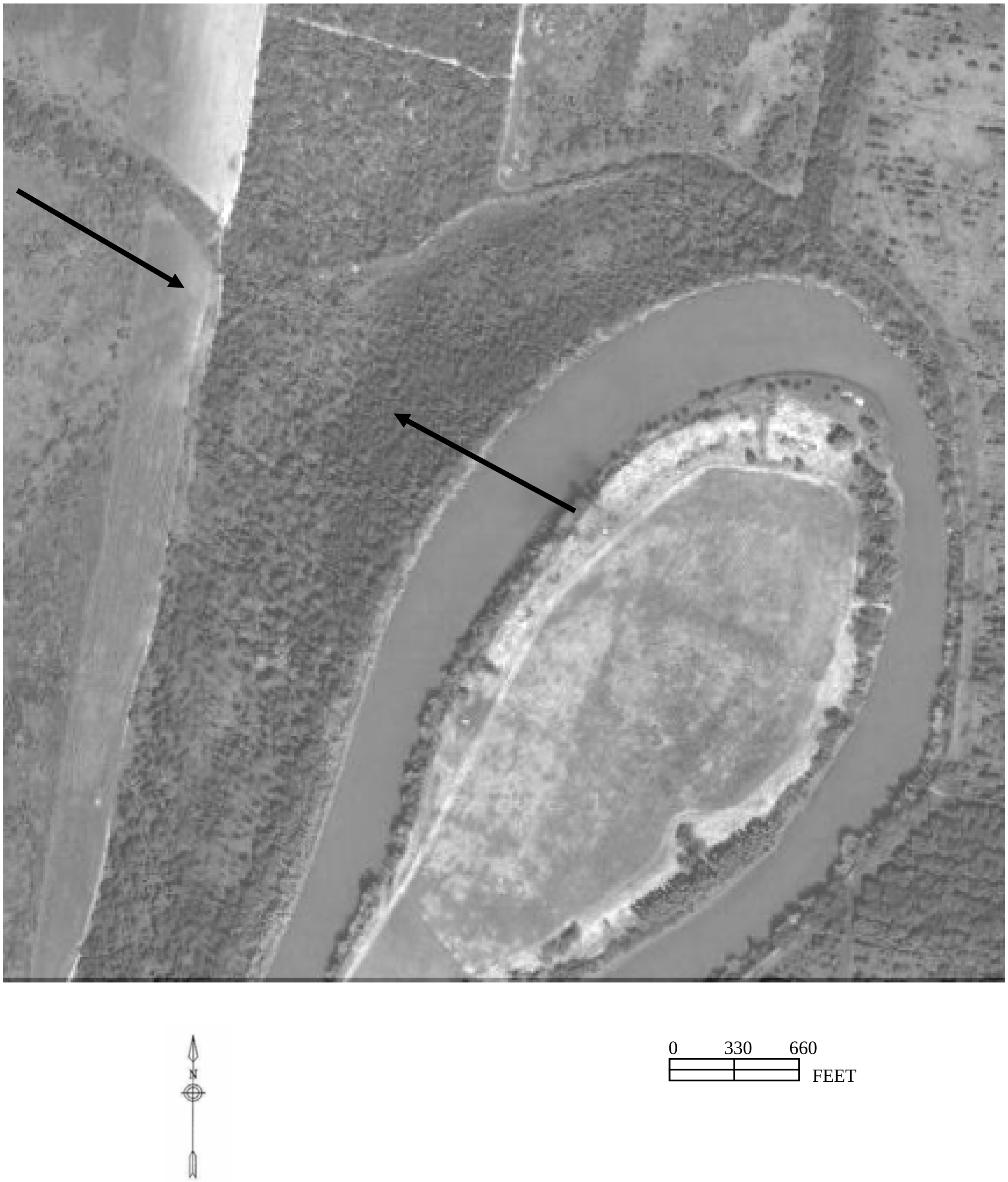

Figure 3A. Satellite Image of Havana Tract (between Arrows)

Urban gardens are valuable because they provide a resource refuge for bees and are sites capable of providing adequate resources to a wide variety of bees typical of the area. There was one scientific study in an urban garden that lasted 15 years. The garden measured approximately 50 X 160 feet. In this garden, 15 genera and 51 species of social and solitary bees were documented. A total of 1782 species of animals and 422 species of plants were recorded and monitored (Owen, 1991).

Although houses and streets surround the Valley Nature Center, it offers an oasis of natural habitat amidst an urban community. This site encompasses five acres of carefully landscaped and designed wildscapes, including a small five-acre thicket of native vegetation representing Upland Thornscrub Forest. The site has sufficient water to sustain plants that were chosen for their attractiveness to birds, butterflies and many other species of animals. These plant species were picked in order to provide for the

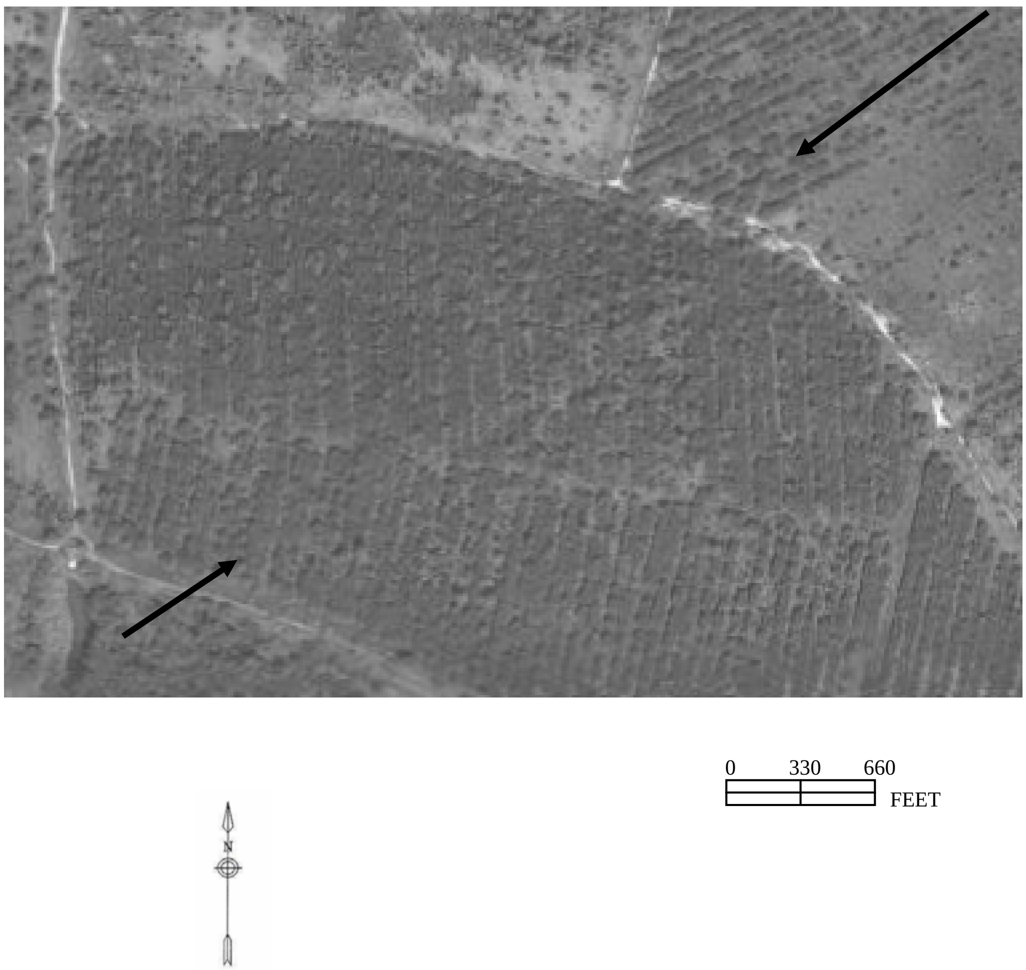

Figure 3B. Satellite Image of La Joya Tract (between Arrows)

Figure 3C. Satellite Image of Valley Nature Center (between Arrows) basic necessities of the animal's life cycle. There are more than 300 species of native plants within this tract (Valley Nature Center Plant List, 2001). The key here is that this site consists of (primarily) native plants and a diversity of bee species would suggest that these urban plots are capable of sustaining a diverse bee population. Many of the plants provide a significant understory growth that should or could be of some value in enhancing the revegetated sites when reintroduced. This five acre garden is extremely diverse, and many rare species of birds, butterflies and odonates as well as an abundance of pollinators have been observed.

Satellite imagery illustrates the overview of the landscapes of the three study sites and the areas surrounding them (Fig. 3A, 3B and 3C). Havana Tract and the Valley Nature Center show areas of solid, lush vegetation while the rows used during the replanting of the La Joya Tract are still quite visible even after all these years.

On closer examination, one can observe the thick, dense vegetation of the Upland Thorn Scrub of the Havana Tract (Fig. 4A). The La Joya Tract exhibits habitat that has been revegetated as seen in Figure 4B. Much of which is guineagrass as seen in the foreground of these photos. The habitat of the Valley Nature Center is influenced by manmade structures, however; the vegetation is enhanced by it along with the pollinators (Fig. 4C).

Figure 4A. Representation of Typical Vegetation of the Havana Tract

Figure 4B. Representation of Typical Vegetation of the La Joya Tract

Figure 4C. Representation of Typical Vegetation of the Valley Nature Center

Habitat Measurements

Bee populations were monitored on the native brush tract and revegetated tract for a period of three years, from 1999 to 2002 and the urban garden site for two years, 2001 – 2003. Observations of the genera of bees and the species of flowering plants that they were foraging upon were taken. A wide range of flowering plant species were observed to determine which bee species were the most important pollinators of specific plants, and whether a bee species was a specialist or generalist. Flowering plant populations were monitored through time to observe the seasonal variability of pollinator guilds. This occurred because different species of plants bloom at various times throughout the year and attract different pollinators. When bee species are monitored through time, their frequency and abundance may be determined. In the revegetated area, the diversity and abundance of the bees should correlate with the viability of the restoration.

Bee guilds were initially monitored at study sites by means of aerial sweeping, and later by field identification. Collection and identification of bee populations from flowering plants using an aerial net was performed. A synoptic bee collection was prepared and representatives were pinned, labeled and identified. Bees collected will be archived within the Texas A&M University Entomology Department Collection. Visual observations were made later, once the bee fauna had been established. This was done to minimize the disturbance to or depletion of the reservoir of bee species present. These observations were recorded as to the species of flowering plants and the genera of bees that were foraging upon them.

Likewise, a botanical inventory was made from plant species collected, to assess species diversity and utilization. Specific plants or patches of plants were monitored for attractiveness to certain species of bees. Plants that attracted these pollinators were collected, pressed and identified. Voucher specimens will be archived at the Tracy Herbarium of Texas A&M University.

Bee Sampling Protocol

Collections and observations continued to be monitored over a three year period of time using the method of Frankie, et al. (1993). This method consists of observations of a 2 X 2 meter square of flowering plants that were observed within the study sites over a period of 10 – 15 minutes. This was replicated three times on specific plants to obtain quantitative data. Visitation to the site took place every two weeks, and the 2 X 2 meter square observations occurred every four weeks. To provide an unbiased sample, these patches were observed in the morning one week and the afternoon in the alternating week. Each bee species was given a unique number that is consistent throughout all the tables to facilitate comparisons and discussion.

CHAPTER IV

RESULTS

Three sites were monitored and surveyed over a period of two to three years each. These sites were the Havana Tract (a natural site that had not been cut), the La Joya Tract (a revegetated site) and the Valley Nature Center Park (urban site with native plants planted for posterity).

The Havana Tract (native brush site) yielded thirteen genera and seventeen bee species during the three year study (Table 1). Of these, six genera and ten species were unique to this site. These included: *Andrena dollomellea, Andrena faceta*, *Diadasia rinconis, Exomalopsis zexmeniae, Mellissodes tepaneca, Xylocopa tabaniformis parkinsoniae, Augochlora aurifera*, *Augochlora azteca*, *Halictus ligatus, Lasioglossum (Dialictus)* spp. and *Lithurgus littoralis.* There were 56 species of vascular plants within 24 families within this site (Table 2).

Table 1. Havana Tract (the native brush site) showing the plants in which each bee species were collected and plant species from which the plant collection was made

Bee spp. no.[a]	Genus	Species	Collected	Plant species
1	*Xylocopa*	*tabaniformis parkinsoniae*	Sep-11-99	*Eysenhardtia texana*
			Sep-11-99	*Malvaviscus drummondii*
2	*Xylocopa*	*strandi*	Sep-11-99	*Cordia boissieri*
			Sep-11-99	*Parkinsonia aculeata*
3	*Augochlora*	*aurifera*	Feb-13-00	*Verbena bipinnatifida*
4	*Halictus*	*ligatus*	Mar-17-01	*Teucrium cubense*
5	*Exomalopsis*	*zexmeniae*	Apr-14-01	*Viguera stenoloba*
6	*Diadasia*	*rinconis*	May-12-01	*Opuntia lindheimerii*
7	*Xylocopa*	*mexicanorum*	Apr-22-00	*Argemone mexicana*
8	*Andrena*	*dolomellea*	Mar-11-00	*Palafoxia texana*
9	*Lasioglossum* (*Dialictus*)	*spp.*	Mar-25-00	*Aphanostephus ramosissimus*
10	*Augochlora*	*azteca*	Mar-25-00	*Verbena quadrangulata*
11	*Lithurgus*	*littoralis*	Nov-04-00	*Opuntia leptocaulis*
12	*Andrena*	*faceta*	Apr-08-00	*Acacia farnesiana*
13	*Augochloropsis*	*metallica*	Mar-25-00	*Cercidium texana*
10	*Augochlora*	*azteca*	Nov-20-99	*Leucophyllum frutescens*
13	*Augochloropsis*	*metallica*	Nov-20-99	*Aloyssia gratissima*
13	*Augochloropsis*	*metallica*	Sep-16-01	*Aloyssia macrostachya*
			Oct-21-01	*Coursettia axillaris*
14	*Melissodes*	*tepaneca*	Sep-25-99	*Leucophyllum frutescens*
15	*Apis*	*mellifera*	Sep-25-99	*Sarcostemma cynanchoides*
			Oct-07-00	*Salvia ballotaeflora*
			Mar-11-00	*Prosopis glandulosa*
16	*Bombus*	*pennsylvanicus*	Jul-01-00	*Acacia rigidula*
3	*Augochlora*	*aurifera*	Jul-01-00	*Acacia wrightii*
17	*Agapostemon*	*texanus*	Jun-17-00	*Lantana macropoda*

[a]Each species was given a unique number that is consistant throughout the tables.

The La Joya tract (revegetated site) yielded three genera and four bee species during the three year study (Table 3). There were no unique species recorded from this site. This revegetated site had 15 families and thirty-one native species of trees and shrubs, many of them planted on the site in 1992 (Table 4). In addition, there were several volunteer species that had invaded the site (see below).

The Valley Nature Center Park (urban site) was very diverse in bee species. It had twelve genera and thirteen species present (Table 5). Of those, there were five unique genera and eight unique species to the site. They were as follows: *Andrena* spp.ST-3, *Ceratina diadonta*, *Perdita tricincta*, *Diadasia enavata*, *Megachile chichimeca*, *Coelioxys texana*, *Ptiloglossa mexicana* and *Agapostemon melleventris*.

Overall there were 18 genera consisting of 25 species of bees found in this study in south Texas over a period of three years.

Table 2. Havana Tract (the native brush site) showing the 56 species of plants identified and grouped within 24 families[a]

Family	Plant species	Common name	Floral Reward P-pollen, N-nectar
Asclepiadaceae	*Sarcostemma cynanchoides*	milkweed vine	P N
Asteraceae	*Aphanostephus ramosissimus*	lazy daisy	P N
	Helianthus annuus	sunflower	P N
	Palafoxia texana	palafoxia	P N
	Verbesina encelioides	cowpen daisy	P N
	Viguiera stenoloba	skeleton-leaf golden eye	P N
Boraginaceae	*Cordia boissieri*	anacahuita	P N
	Ehretia anacua	anaqua	N
Cactaceae	*Opuntia leptoc*aulis	tasajillo	P N
	Opuntia lindheimerii	prickly pear cactus	P N
Celastraceae	*Schaefferia cuneifolia*	yaupon	P
Ebenaceae	*Dyospyros texana*	persimmon	N
Fabaceae	*Acacia berlandieri*	guajillo	P N
	Acacia farnesiana	huisache	P N
	Acacia rigidula	blackbrush	P N
	Acacia schaffneri	huisachillo	P
	Acacia wrightii	Wright's acacia	P N
	Cercidium texanum	palo verde	N
	Coursetia axillaris	babybonnets	P N
	Eysenhardtia texana	kidneywood	N
	Leucaena pulverulenta	tepeguaje	N
	Mimosa pigra	zarza	N
	Parkinsonia aculeata	retama	N
	Pithecellobium flexicaulis	ebony	N
	Pithecellobium pallens	tenaza	N
	Prosopis glandulosa	mesquite	N
Lamiaceae	*Lamium amplexicaule*	henbit	P N
	Salvia ballotaeflora	shrubby blue sage	P N
	Salvia coccinea	scarlet sage	P N
	Teucrium cubense	germander	P N
Liliaceae	*Yucca treculeana*	spanish dagger	P N
Malvaceae	*Malvaviscus drummondii*	turk's cap	P N

Table 2 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
Oleaceae	*Forestiera angustifolia*	elbowbush	N
	Fraxinus berlandieriana	ash	P
Papaveraceae	*Argemone mexicana*	prickly poppy	P
Ranunculaceae	*Clematis drummondii*	old man's beard	P N
Rhamnaceae	*Condalia hookeri*	brasil	N
	Karwinskia humboldtiana	coyotillo	P N
	Ziziphus obtusifolia	lotebush	N
Sapindaceae	*Sapindus drummondii*	soapberry	N
Sapotaceae	*Bumelia celestrina*	coma	N
Scrophulariaceae	*Leucophyllum frutescens*	cenizo	P
Simaroubaceae	*Castela erecta*	allthorn	P
Solanaceae	*Lycium berlandieri*	wolfberry	N
	Solanum elaeagnifolium	silver leaf nightshade	P N
Ulmaceae	*Celtis laevigata*	hackberry	N
	Celtis pallida	granjeno	N
Verbenaceae	*Aloysia gratissima*	whitebrush	P N
	Aloysia macrostachya	sweetstem	P N
	Lantana horrida	Texas lantana	P N
	Lantana macropoda	desert lantana	P N
	Verbena bipinnatifida	Dakota vervain	P N
	Verbena quadrangulata	beaked vervain	P N
Viscaceae	*Phoradendron tomentosum*	mistletoe	N
Vitaceae	*Cissus incisa*	marine ivy	P N
Zygophyllaceae	*Guaiacum angustifolium*	guayacan	N

[a]Both the scientific and common names are provided along with the type of bee floral rewards each produces.

Andrena spp. ST – 3, is believed to be a newly discovered species and is being described for publication elsewhere. This gives significance to such small urban sites that have the capability to yield new species as well as enhancing the diversity and

Table 3. La Joya Tract (the revegetated site) illustrating the plants in which each bee species was collected and the plant species from which the plant collection was made

Bee spp. no.	Genus	Species	Collected	Plant species
7	*Xylocopa*	*mexicanorum*	Sep-11-99	*Clematis drummondii*
			Sep-11-99	*Cordia boissieri*
2	*Xylocopa*	*strandi*	Sep-25-99	*Mimosa pigra*
			Sep-25-99	*Cordia boissieri*
15	*Apis*	*mellifera*	Jun-17-00	*Leucaena pulverulenta*
17	*Agapostemon*	*texanus*	Jul-01-00	*Clematis drummondii*

Table 4. La Joya Tract (the revegetated site) showing the 31 plant species utilized in the restoration grouped within 15 families[a]

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
Boraginaceae	Cordia boissieri	anacahuita	P N
	Ehretia anacua	anacua	N
Cactaceae	Opuntia lindheimeri	pricklypear cactus	P N
Celastraceae	Schaefferia cuneifolia	yaupon	P
Ebenaceae	Diospyros texana	persimmon	N
Fabaceae	Acacia berlandieri	guajillo	P N
	Acacia farnesiana	huisache	P N
	Acacia rigidula	blackbrush	P N
	Acacia schaffneri	huisachillo	P
	Acacia wrightii	Wright's acacia	P N
	Cercidium texanum	palo verde	N
	Coursetia axillaris	babybonnets	P N
	Eysenhardtia texana	kidneywood	N
	Parkinsonia aculeata	retama	N
	Pithecellobium flexicaulis	ebony	N
	Pithecellobium pallens	tenaza	N
	Prosopis glandulosa	mesquite	N
Malpighiaceae	Malpighia glabra	manzanita	
Oleaceae	Forestiera angustifolia	elbowbush	N
	Fraxinus berlandieriana	ash	P
Rhamnaceae	Condalia hookeri	brasil	N
	Ziziphus obtusifolia	lotebush	N
Rutaceae	Zanthoxylum fagara		
Sapotaceae	Bumelia celastrina	coma	N
Scrophulariaceae	Leucophyllum frutescens	cenizo	P
Solanaceae	Capsicum annuum		
	Lycium berlandieri	wolfberry	N
Ulmaceae	Celtis laevigata	hackberry	N
	Celtis pallida	granjeno	N
Verbenaceae	Aloysia gratissima	whitebrush	P N
Zygophyllaceae	Guaiacum angustifolium	guayacan	N

[a]Scientific and common names are provided along with the floral rewards produced by each.

Table 5. Valley Nature Center (the urban garden site) listing the plants in which each bee species were collected and plant species which comprises the plant collection

Bee spp. no.	Genus	Species	Collected	Plant species
18	*Ceratina*	*diodonta*	Mar-02-02	*Rivina humilis*
19	*Andrena*	ST-3 (new species)	Mar-16-02	*Buddleja sessifolia*
20	*Agapostemon*	*melliventris*	Oct-11-03	*Lantana horrida*
13	*Augochloropsis*	*metallica*	Nov-22-03	*Plumbago scandens*
			Dec-06-03	*Dicliptera vahliana*
15	*Apis*	*mellifera*	Mar-01-03	*Pluchea carolinensis*
			Feb-01-03	*Lantana macropoda*
			Feb-01-03	*Salvia misella*
			Mar-15-03	*Pisonia aculeata*
			Apr-13-02	*Citharexyllum berlandieri*
7	*Xylocopa*	*mexicanorum*	Mar-16-02	*Acacia farnesiana*
16	*Bombus*	*pennsylvanicus*	Mar-16-02	*Sophora secundiflora*
21	*Ptiloglossa*	*mexicana*	Feb-16-02	*Solanum erithanthum*
15	*Apis*	*mellifera*	Apr-27-02	*Erythrina herbacea*
22	*Diadasia*	*enevata*	Jun-22-02	*Helianthus annuus*
23	*Perdita*	*tricincta*	Feb-16-02	*Guaiacum angustifolia*
17	*Agapostemon*	*texanus*	Feb-16-02	*Acacia berlandierii*
24	*Megachile*	*chichimeca*	Jul-06-02	*Aloyssia macrostachya*
25	*Coelioxys*	*texana*	Jul-06-02	*Aloyssia macrostachya*

Table 6. Valley Nature Center (the urban garden site) showing the 317 species of plants identified and grouped into 77 families[a]

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
Acanthaceae	*Carlowrightia parviflora*	carlowrightia	
	Dicliptera vahliana	dicliptera	
	Justicia runyonii	Runyon's waterwillow	
	Ruellia spp.	wild petunia	
	Siphonoglossa pilosella	tube tongue	
Alismataceae	*Sagittaria longiloba*	arrowhead	N
Amaranthaceae	*Alternathera caracasana*	chaffflower	
	Amaranthus berlandieri	carelessweed	
	Amaranthus palmeri	Palmer carelessweed	
	Celosia nitida	celosia	
	Iresine palmeri	Palmer's bloodleaf	
Amaryllidaccae	*Agave americana*	century plant	P N
	Agave desmettiana		P N
	Agave ferox		P N
	Agave guingola		P N
	Agave lecheguilla	lechuguilla	P N
	Agave lophantha		P N
	Agave scabra	rough agave	P N
	Agave weberi	Weber agave	P N
	Agave xylonacantha		P N
	Manfreda longiflora	Runyon's huaco	
	Manfreda variegata	huaco	
Apiaceae	*Hydrocotyle bonariensis*	sombrerillo	
Apocynaceae	*Macrosiphonia macrosiphon*	flor de San Juan	
Aristolochiaceae	*Aristolochia erecta*	swanflower	
Asclepiadaceae	*Asclepias curassavica*	Mexican milkweed	P N
	Asclepias oenotheroides	hierba de Zizotes	P N
	Cynanchum angustifolium	marsh swallow-wort	P N
	Cynanchum barbigerum	climbing milkweed	P N
	Sarcostemma cynanchoides	twinevine	P N
Asteraceae	*Ambrosia* spp.	ragweed	P
	Aphanostephus ramosissimus	lazy daisy	P N
	Aphanostephus skirrhobasis	lazy daisy	
	Aster subulatus	herba del Marrano	P N
	Borrichia frutescens	sea ox eye daisy	
	Calyptocarus vialis	prostrate lawnflower	
	Coreopsis nuecensis	tick seed coreopsis	P N
	Coreopsis tinctoria	golden wave	P N
	Erigeron procumbens	fleabane	
	Eupatorium azureum	blue bonseset	P N
	Eupatorium betonicifolium	Betony eupatorium	P N
	Eupatorium greggii	Gregg's eupatorium	P N
	Eupatorium incarnatum	mistflower	P N
	Eupatorium odoraturm	crucita	P N
	Florestina tripteris	sticky palofixia	
	Gnaphalium pensilvanicum	cudweed	
	Helianthus annuus	sunflower	P N

Table 6 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
	Heterotheca latifolia	camphor weed	
	Melampodium cinereum	blackfoot daisy	
	Palafoxia texana	palafoxia	P N
	Parthenium hysterophorus	false ragweed	
	Perezia runcinata	peonia	
	Pluchea odorata	marsh fleabane	P N
	Pluchea carolinensis		P N
	Pyrrhopappus spp	false dandelion	
	Ratibida columnaris	Mexican hat	
	Simsia calva	bush sunflower	
	Solidago sempervirens	seaside goldenrod	P N
	Thymophylla spp.	tiny tim	
	Trixis inula	Mexican trixis	
	Verbesina encelioides	cowpen daisy	P N
	Verbesina microptera	frostweed	P N
	Viguiera stenoloba	skeleton-leaf daisy	P N
	Wedelia spp.		
Basellaceae	*Anredera* spp.	maderia vine	
Boraginaceae	*Cordia boissieri*	anacahuita	P N
	Ehretia anacua	anaqua	N
	Heliotropium angiospermum	taperleaf heliotrope	
	Heliotropium curassavicum	seaside heliotrope	
	Tournefortia volubilis	Mexican tournefortia	
Brassicaceae	*Lepidium austrinum*	peppergrass	
	Lesquerella spp.	bladderpod	
Bromeliaceae	*Hechtia glomerata*	guapilla	
	Tillandsia baileyi	Bailey's ball moss	
	Tillandsia recurvata	ball moss	
	Tillandsia usneoides	Spanish moss	
Cactaceae	*Acanthocereus horridus*		
	Acanthocereus pentagonus	nightblooming cereus	P N
	Acanthocereus sudinermis		P N
	Ancistrocactus scheeri	fishhook cactus	P N
	Astrophytum asterias	sanddollar cactus	P N
	Astrophytum ornatum	star cactus	P N
	Carnegiea gigantea	saguaro	P N
	Cereus peruvianus	apple cactus	P N
	Cleistocactus baumannii		P N
	Cleistocactus strausii		P N
	Coryphantha macromeris var. runyonii		P N
	Echinocactus texensis	horse crippler cactus	P N
	Echinocereus alberti	black lace cactus	P N
	Echinocereus berlandieri	Berlandier's alicoche	P N
	Echinocereus blanckii	alicoche	P N
	Echinocereus enneacanthus	pitaya	P N
	Echinocereus fitchii	Fitch's rainbow	P N
	Echinocereus papillosus var. angusticeps	yellow lady finger	P N

Table 6 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
	Echinocereus papillosus var. papillosus	yellow pitaya	P N
	Echinocereus pentalophus	lady finger cactus	P N
	Echinopsis spp.	easter lily cactus	P N
	Escobaria runyonii	Tom Thumb cactus	P N
	Hamatacactus setispinus var. hamatus	fish hook cactus	P N
	Hamatacactus setispinus var. setaceus	twisted rib cactus	P N
	Hamatacactus sinuatus	Rio Grande barrel	P N
	Hylocereus spp.		P N
	Mammillaria heyderi	pin cushion cactus	P N
	Mammillaria multiceps	hair covered cactus	P N
	Mammillaria sphaerica		P N
	Neobuxbaumia polylophus		P N
	Nopalea coccinellifera	nopalito	P N
	Nyctocereus serpentinus	snake cactus	P N
	Opuntia compressa	eastern pricklypear	P N
	Opuntia engelmannii	Englemann's cactus	P N
	Opuntia engelmanni var. linguiformis	cow tongue cactus	P N
	Opuntia ficus-indica		P N
	Opuntia galapagaia	Galapagos Island cactus	P N
	Opuntia imbricata	cholla	P N
	Opuntia leptocaulis	tasajillo	P N
	Opuntia microdasys	bunny ears	P N
	Opuntia santa-rita		P N
	Opuntia schottii	dog cholla	P N
	Opuntia undulata		P N
	Pereskiopsis spp.		P N
	Selenicereus spinulosus		P N
	Stenocereus marginatus	Mexican organpipe	P N
	Stenocereus pruinosus		P N
	Stetsonia coryne		P N
	Thelocactus bicolor	glory of Texas	P N
Capparidacae	*Polanisia dodecandra*	clammy weed	
Celastraceae	*Maytenus phyllanthoides*	leatherleaf	
	Mortonia greggii	mortonia	
	Schaefferia cuneifolia	desert yaupon	P
Chenopodiaceae	*Chenopodium ambrosioides*	epazote	
	Chenopodium berlandieri	stinkweed	
Cochlospermaceae	*Amoreuxia wrightii*	yellow show	
Commelinaceae	*Commelina erecta*	widow's tears	
	Tradescantia micrantha	spiderwort	
Convolvulaceae	*Evolvulus alsinoides*	ojo de vibora	P N
	Evolvulus sericeus	white evolvulus	P N
	Ipomoea carnea	bush morningglory	P N
	Ipomoea hederacea	blue morningglory	P N
	Ipomoea sinuata	Alamo vine	P N
Crassulaceae	*Kalanchoe delagoensis*	maternity plant	

Table 6 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
Cucurbitaceae	*Ibervillea lindheimeri*	globeberry	P N
Cyperaceae	*Cyperus rotundus*	nut grass	
	Dichronema colorata	white top sedge	
	Eleocharis parvula	dwarf spikerush	
	Scirpus spp.	bulrush	
Ebenaceae	*Diospyros texana*	chapote	P N
Ephedraceae	*Ephedra antisyphilitica*	Mormon tea	P N
Euphorbiaceae	*Adelia vaseyi*	Vasey's adelia	
	Argythamnia spp.	wild mercury	
	Bernardia myricifolia	oreja de raton	
	Croton cortesianus	Cortes' croton	
	Croton humilis	low croton	
	Croton incanus	Torrey croton	
	Jatropha dioica	leatherstem	
	Tragia glanduligera	brush noseburn	
Fabaceae	*Acacia berlandieri*	guajillo	P N
	Acacia farnesiana	huisache	P N
	Acacia greggii	catclaw	N
	Acacia rigidula	black brush	P N
	Acacia shaffneri	huisachillo	P
	Acacia wrightii	Wright's acacia	P N
	Baptisia leucophaea	plains wild indigo	N
	Caesalpinia mexicana	Mexican caesalpinia	
	Cassia splendida		P N
	Cercidium texanum	palo verde	N
	Chamaecrista faciculata	partridgepea	
	Coursetia axillaris	baby bonnets	P N
	Crotalaria incana	rattlepod;chipilin	
	Dalea scandens		P N
	Desmanthus virgatus	bundleflower	
	Erythrina arborea	coral bean	
	Eysenhardtia texana	kidneywood	N
	Leucaena leucocephala	popinac	
	Leucaena pulverulenta	tepeguaje	N
	Lupinus texensis	Texas bluebonnet	P N
	Medicago polymorpha	Burrclover	P N
	Mimosa malacophylla	raspilla	
	Mimosa wherryana	Wherry's mimosa	
	Neptunia pubescens	yellow puff	
	Parkensonia aculeata	retama	P N
	Pithecellobium flexicaulis	Texas ebony	N
	Pithecellobium pallens	tenaza	N
	Prosopis glandulosa	honey mesquite	P N
	Schrankia latidens	sensitive briar	
	Senna bauhinioides	two-leaved senna	
	Sophora secundiflora	Texas mountain laurel	
	Sophora tomentosa	yellow sophora	
Flacourtiaceae	*Xylosma flexuosa*	brush holly	
Fumariaceae	*Corydalis micrantha*	scrambled eggs	
Geraniaceae	*Geranium* spp.	wild geranium	P N

Table 6 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
Hydrophyllaceae	*Phacelia patuliflora*	blue phacelia	
Iridaceae	*Sisyrinchium biforme*	blue-eyed grass	
Koeberliniaceae	*Koeberlinia spinosa*	allthorn; junco	N
Lamiaceae	*Lamium amplexicaule*	henbit	P N
	Monarda spp.	horsemint	P N
	Salvia ballotaeflora	shrubby blue sage	P N
	Salvia coccinea	scarlet sage	P N
	Salvia misella		P N
	Stachys drummondii	pink mint	P N
	Teucrium canadense	American germander	P N
Lilaceae	*Echeandia chandleri*	lila de los llanos	
	Yucca treculeana	Spanish dagger	P N
Loganiaceae	*Buddleja sessiliflora*	tepozan	
Lythraceae	*Heimia salcifolia*	willow-leaf heimia	
Malpighiaceae	*Malpighia glabra*	manzanita	
Malvaceae	*Abutilon hypoleucum*	Rio Grande abutilon	
	Abutilon trisulcatum	amantillo	
	Allowissadula lozanii	lozano	
	Bastardia viscosa	Mexican bastardia	
	Billieturnera helleri	copper sida	
	Herissantia crispa	netvein herissantia	
	Hibiscus martianus	heart-leaf hibiscus	
	Malvastrum spp.	malva loca	
	Malvaviscus arboreus var. drummondii	turk's cap	P N
	Meximalva filipes	blue sida	
	Sida rhombifolia	arrowleaf sida	
Meliaceae	*Melia azedarach*	chinaberry	
Menispermaceae	*Cocculus diversifolius*	snailseed	
Nyctaginaceae	*Acleisanthes obtusa*	angel trumpets	
	Boerhavia spp.	spiderling	
	Pisonia aculeata	devil's claw	
Nymphaeaceae	*Nymphaea mexicana*	yellow waterlily	
Oleaceae	*Forestiera angustifolia*	elbowbush	N
	Fraxinus berlandieriana	fresno	P
Onagraceae	*Gaura* spp.	wild honeysuckle	
	Ludwigia octovalvis	primrose willow	
	Ludwigia peploides	water primrose	
	Oenothera speciosa	evening primrose	
Oxalidaceae	*Oxalis dichondrifolia*	agrito	
	Oxalis drummondii	woodsorrel	
	Oxalis stricta	yellow woodsorrel	
Palmaceae	*Phoenix canariensis*	Canary Isl. date palm	
	Sabal texana	Texas sabal palm	
Papaveraceae	*Argemone sanguinea*	white pricklypoppy	P
	Argemone mexicana	yellow pricklypoppy	P
Passifloraceae	*Passiflora filipes*		N
	Passiflora foetida var. gossypifolia	corona de Christo	N
	Passiflora suberosa		N

Table 6 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
	Passiflora tenuiloba	longhorn passionvine	N
Phytolaccaceae	*Petiveria alliacea*	garlic guineaweed	
	Phaulothamnus spinescens	snake eyes	
	Rivina humilis	pigeonberry	
Plantaginaceae	*Plantago* spp.	plantain	P
Plumbaginaceae	*Plumbago scandens*	hierba de Alacran	
Poaceae	*Andropogon glomeratus*	bushy bluestem	
	Arundo donax	giant cane	
	Cenchrus spp	sandbur	
	Chloris spp.	windmillgrass	
	Cynodon dactylon	bermudagrass	
	Pennisetum ciliare	buffelgrass	
	Setaria spp.		
	Urochloa maxima	guinea grass	
Polemoniaceae	*Phlox drummondii*	Drummond's phlox	
Polygonaceae	*Antigonon leptopus*	corona vine	
	Rumex chysocarpus	dock	P
Portulaceae	*Portulaca pilosa*	chisme	
	Talinum angustissimum	yellow flameflower	
	Talinum paniculatum	pink baby's breath	
Ranunculaceae	*Clematis drummondii*	old man's beard	P N
Rhamnaceae	*Colubrina texensis*	hog plum	
	Condalia hookeri	brasil	N
	Condalia spathulata	knifeleaf condalia	N
	Karwinskia humboldtiana	coyotillo	P N
	Ziziphus obtusifolia	lotebush	N
Rosaceae	*Rubus trivialis*	dewberry	P N
Rubiaceae	*Chiococca alba*	David's milkberry	
	Randia rhagocarpa	crucillo	
Rutaceae	*Amyris madrensis*	S. Madre torchwood	
	Amyris texana	Texas torchwood	
	Esenbeckia runyonii	limoncillo	
	Helietta parvifolia	barreta	
	Zanthoxylum fagara	colima	
	Zanthoxylum hirsutum	toothache tree	
Saliaceae	*Salix nigra*	black willow	P N
Sapindaceae	*Sapindus saponaria*	soapberry	N
	Urvillea ulmaceae	elm-leaf urvillea	N
	Cardiospermum halicacabum	common balloon vine	N
Sapotaceae	*Bumelia celastrina*	coma	N
Scrophulariaceae	*Leucophyllum frutescens*	cenizo	P
Simaroubaceae	*Castela erecta*	amargosa	P
Solanaceae	*Capsicum annuum*	chile piquin	
	Lycium berlandieri	Berlandier wolfberry	N
	Lysopersicon esculenta	wild tomato	
	Nicotiana glauca	tree tobacco	
	Nicotiana repanda	fiddleleaf tobacco	
	Quincula lobata	purple ground cherry	
	Solanum americanum	nightshade	
	Solanum elaeagnifolium	silver leaf nightshade	P N

Table 6 (continued)

Family	Plant species	Common name	Floral reward P-pollen, N-nectar
	Solanum erianthum	potato tree	
	Solanum triquetrum	Texas nightshade	
Sterculiaceae	*Ayenia limitaris*	ayenia	
	Melochia tomentosa	wooly pyramid bush	
	Waltheria indica	hierba del Soldado	
Taxodiaceae	*Taxodium mucronatum*	Montez.bald cypress	
Typhaceae	*Typha domingensis*	cattail	
Ulmaceae	*Celtis laevigata*	sugar hackberry	N
	Celtis pallida	granjeno	N
	Ulmus crassifolia	cedar elm	P N
Urticaceae	*Parietaria pensylvanica*	pellitory	
	Urtica chamaedryoides	stinging weed	
Verbenaceae	*Aloysia gratissima*	whitebrush	P N
	Aloysia macrostachya	sweetstem	P N
	Citharexylum berlandieri	fiddlewood	
	Citharexylum brachyanthum	mission fiddlewood	
	Lantana camara	West Indian lantana	N
	Lantana horrida	Texas lantana	P N
	Lantana macropoda	desert lantana	P N
	Lantana microcephala	hammock lantana	N
	Lippia alba	bushy lippia	
	Lippia graveolens	desert oregano	
	Phyla nodiflora	Texas frog fruit	
	Phyla strigulosa	diamondleaf frog fruit	
	Verbena bipinnatifida	dakota vervain	P N
	Verbena offinalis subsp. *halei*	slender vervain	P N
	Verbena quadrangulata	beaked vervain	P N
Viscaceae	*Phoradendron tomentosum*	mistletoe	N
Vitaceae	*Cissus incisa*	marine ivy	P N
Zygophyllaceae	*Guaiacum angustifolium*	guayacan	N

[a]Both the scientific and common names are shown along with the type of floral reward (if known) provided for bees.

Table 7. Comparison of bees and their plant associations by site[a]

Site	Plant family	Plant species	Bee species
Havana	Asclepiadaceae	*Sarcostemma cynanchoides*	*Apis mellifera*
	Asteraceae	*Aphanostephus ramosissimus*	*Lasioglossum (Dialictus)* spp.
		Palafoxia texana	*Andrena dollomellea*
		Viguera stenoloba	*Exomalopsis zexmeniae*
	Boraginaceae	*Cordia boissieri*	*Xylocopa strandi*
	Cactaceae	*Opuntia leptocaulis*	*Lithurgus littoralis*
		Opuntia lindheimerii	*Diadasia rinconis*
	Fabaceae	*Acacia farnesiana*	*Andrena faceta*
		Acacia rigidula	*Bombus pennsylvanicus*
		Acacia wrightii	*Augochlora aurifera*
		Cercidium texana	*Augochloropsis metallica*
		Coursetia axillaris	*Augochloropsis metallica*
		Eysenhardtia texana	*Xylocopa tabaniformis parkinsoniae*
		Parkinsonia aculeata	*Xylocopa strandi*
		Prosopis glandulosa	*Apis mellifera*
	Lamiaceae	*Salvia ballotiflora*	*Apis mellifera*
		Teucrium cubense	*Halictus ligatus*
	Malvaceae	*Malvaviscus drummondii*	*Xylocopa tabaniformis parkinsoniae*
	Papaveraceae	*Argemone mexicana*	*Xylocopa mexicanorum*
	Scrophulariaceae	*Leucophyllum frutescens*	*Augochlora azteca*
			Melissodes tepaneca
	Verbenaceae	*Aloyssia gratissima*	*Augochloropsis metallica*
		Aloyssia macrostachya	*Augochloropsis metallica*
		Lantana macropoda	*Agapostemon texanus*
		Verbena bipinnatifida	*Augochlora aurifera*
		Verbena quadrangulata	*Augochlora azteca*
La Joya	Boraginaceae	*Cordia boissieri*	*Xylocopa mexicanorum*
			Xylocopa strandi
	Fabaceae	*Leucaena pulverulenta*	*Apis mellifera*
		Mimosa pigra	*Xylocopa strandi*
	Ranunculaceae	*Clematis drummondii*	*Agapostemon texanus*
			Xylocopa mexicanorum
Valley Nature Center	Acanthaceae	*Dicliptera vahliana*	*Augochloropsis metallica*
	Asteraceae	*Helianthus annuus*	*Diadasia enavata*
		Pluchea carolinensis	*Apis mellifera*
	Boraginaceae	*Cordia boissieri*	*Xylocopa mexicanorum*
	Fabaceae	*Acacia berlandierii*	*Agapostemon texanus*
		Acacia farnesiana	*Xylocopa mexicanorum*
		Erythrina herbacea	*Apis mellifera*
		Sophora secundiflora	*Bombus pennsylvanicus*
	Lamiaceae	*Salvia misella*	*Apis mellifera*
	Loganiaceae	*Buddleja sessiflora*	*Andrena* spp. ST-3
	Nyctaginaceae	*Pisonia aculeata*	*Apis mellifera*

Table 7 (continued)

Site	Plant family	Plant species	Bee species
	Phytolaccaceae	*Rivina humilis*	*Ceratina diodonta*
	Plumbaginaceae	*Plumbago scandens*	*Augochloropsis metallica*
	Solanaceae	*Solanum erithanum*	*Ptiloglossa mexicana*
	Verbenaceae	*Aloysia macrostachya*	*Megachile chichimeca*
			Coelioxys texana
		Citharexyllum berlandieri	*Apis mellifera*
		Lantana horrida	*Agapostemon melliventris*
		Lantana macropoda	*Apis mellifera*
	Zygophyllaceae	*Guaiacum angustifolia*	*Perdita tricincta*

[a]Havana and La Joya Tracts were studied for a period of three years while the Valley Nature Center had two years of collecting and observations performed.

survivorship of species in the area. The park contains 317 species of vascular plants grouped into 77 families along with abundant water supply (Table 6).

After plotting the observational data for all three sites by year, there was a dramatic difference in plants and bees between with the Havana Tract (Fig. 5A, 5B and 5C) and the La Joya Tract (Fig. 6A, 6B and 6C) as well as the Valley Nature Center (Fig 7A, 7B, 8A and 8B). The La Joya Tract had only three genera and four species of bees present in the observational data as well as the collection data. These species were predominantly collected or observed on plant species that were not involved in the land restoration but were volunteers (Table 7). Along with the volunteer species, there were 26 that provided nectar (Table 4) as its floral reward while only 12 provided a pollen floral reward. Some plant species offered both pollen and nectar.

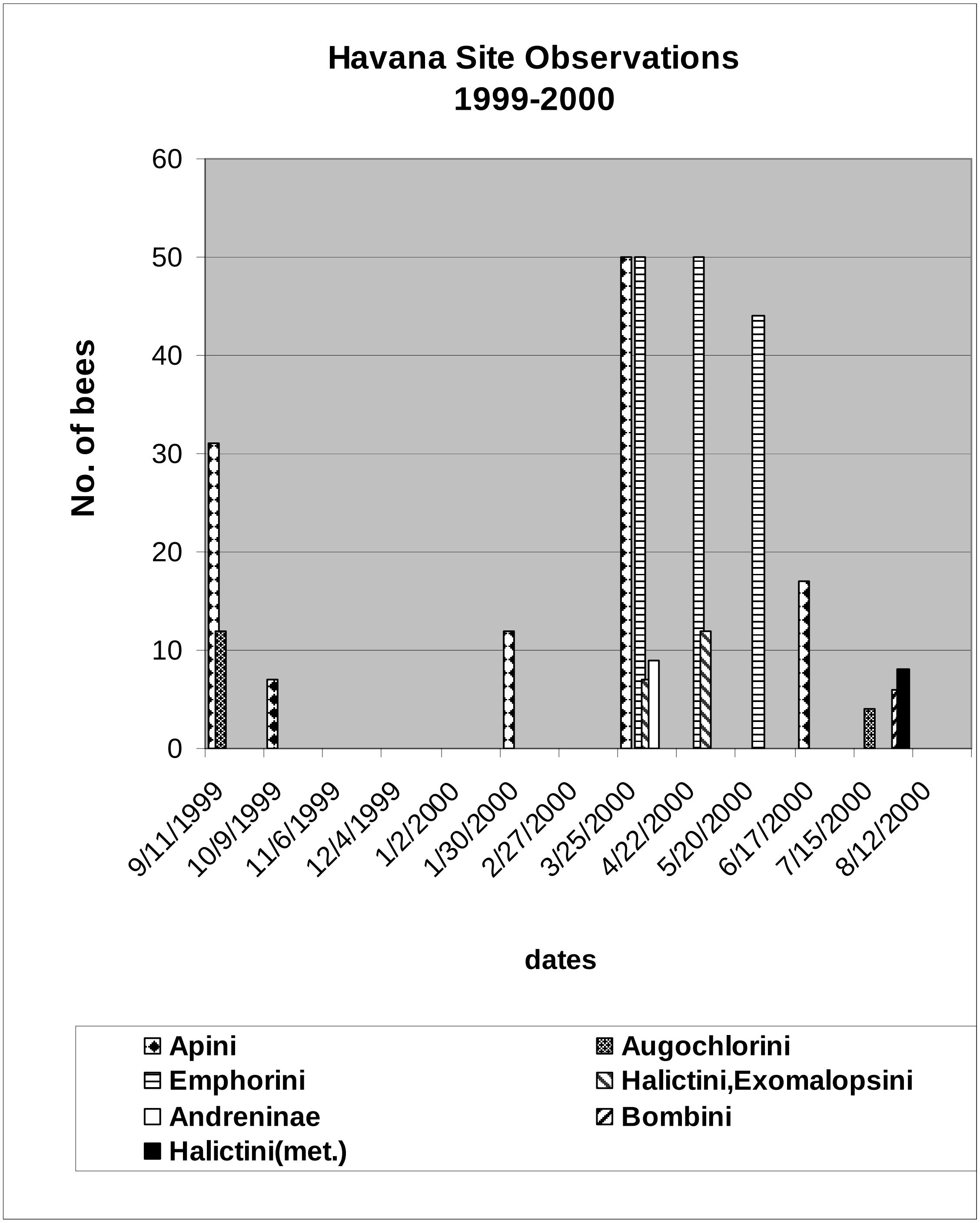

Figure 5A. Havana Site Observations 1999-2000

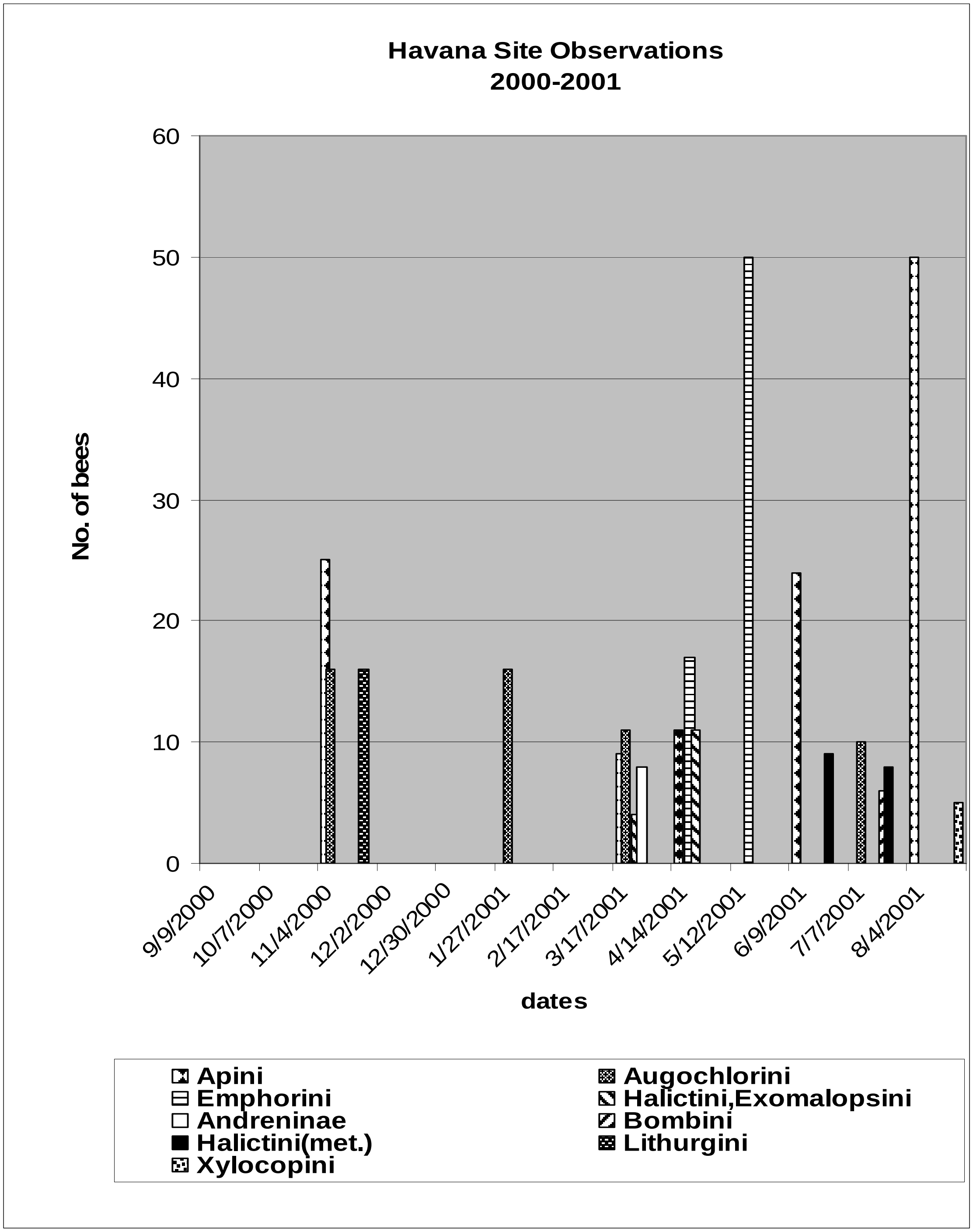

Figure 5B. Havana Site Observations 2000-2001

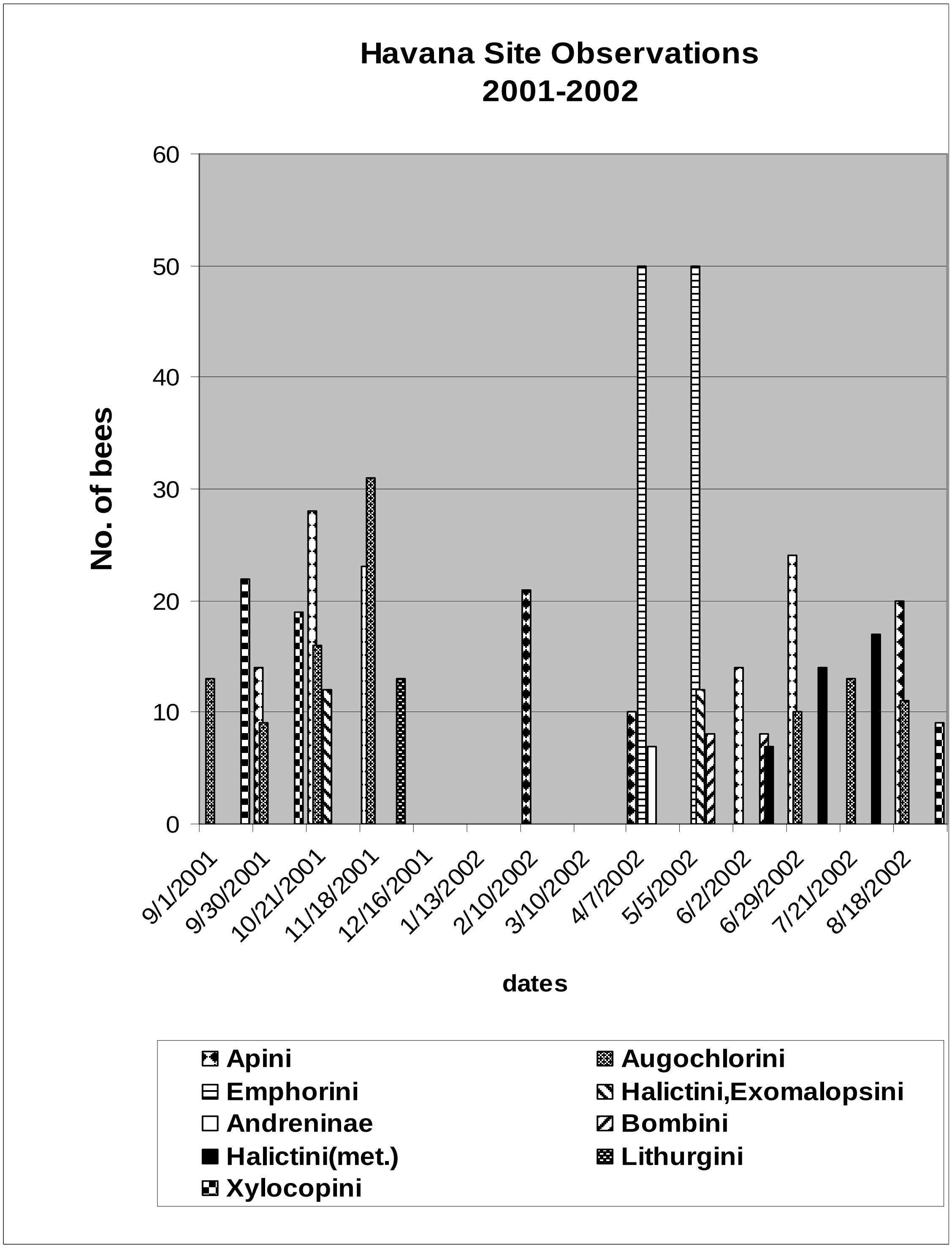

Figure 5C. Havana Site Observations 2001-2002

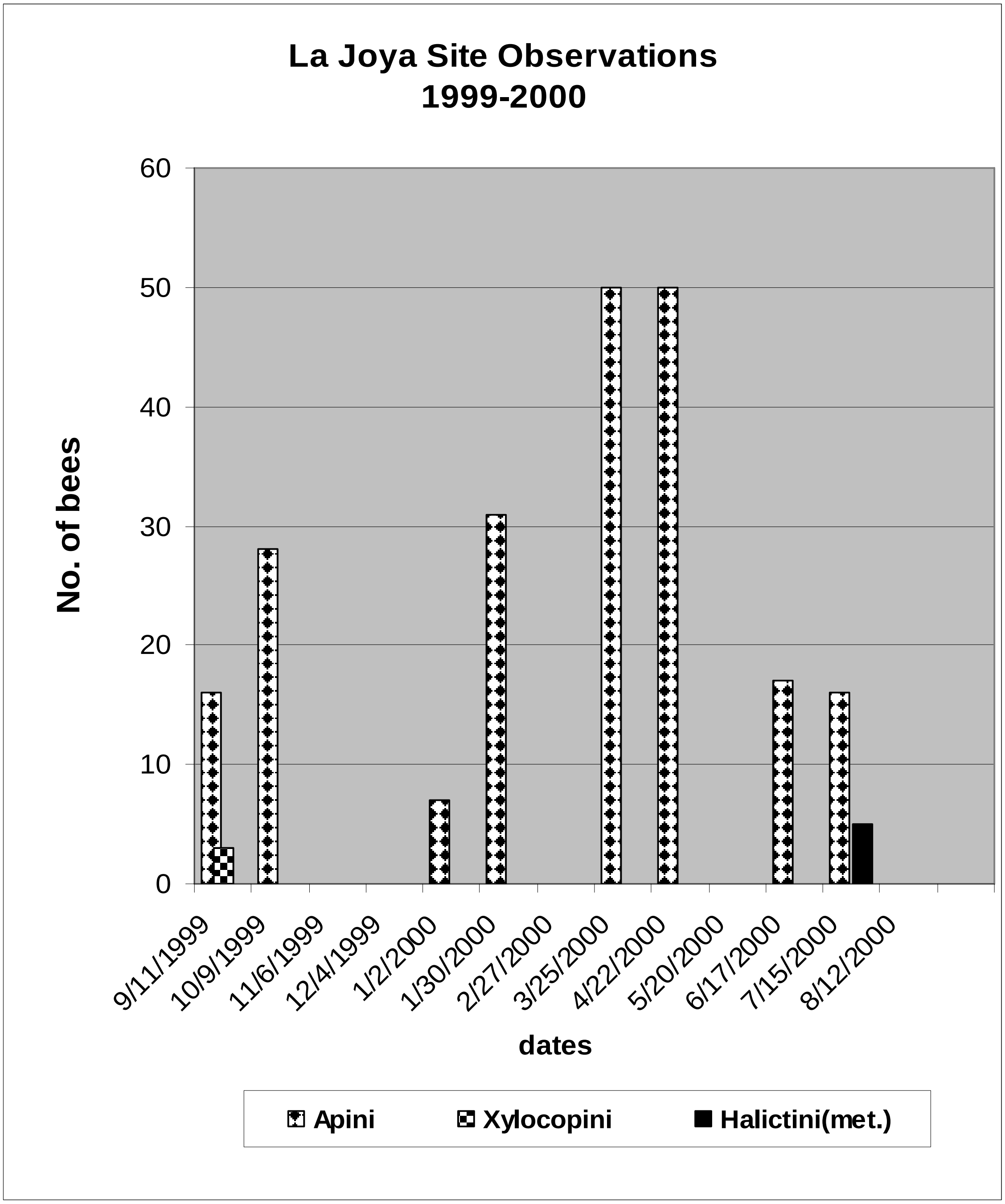

Figure 6A. La Joya Site Observations 1999-2000

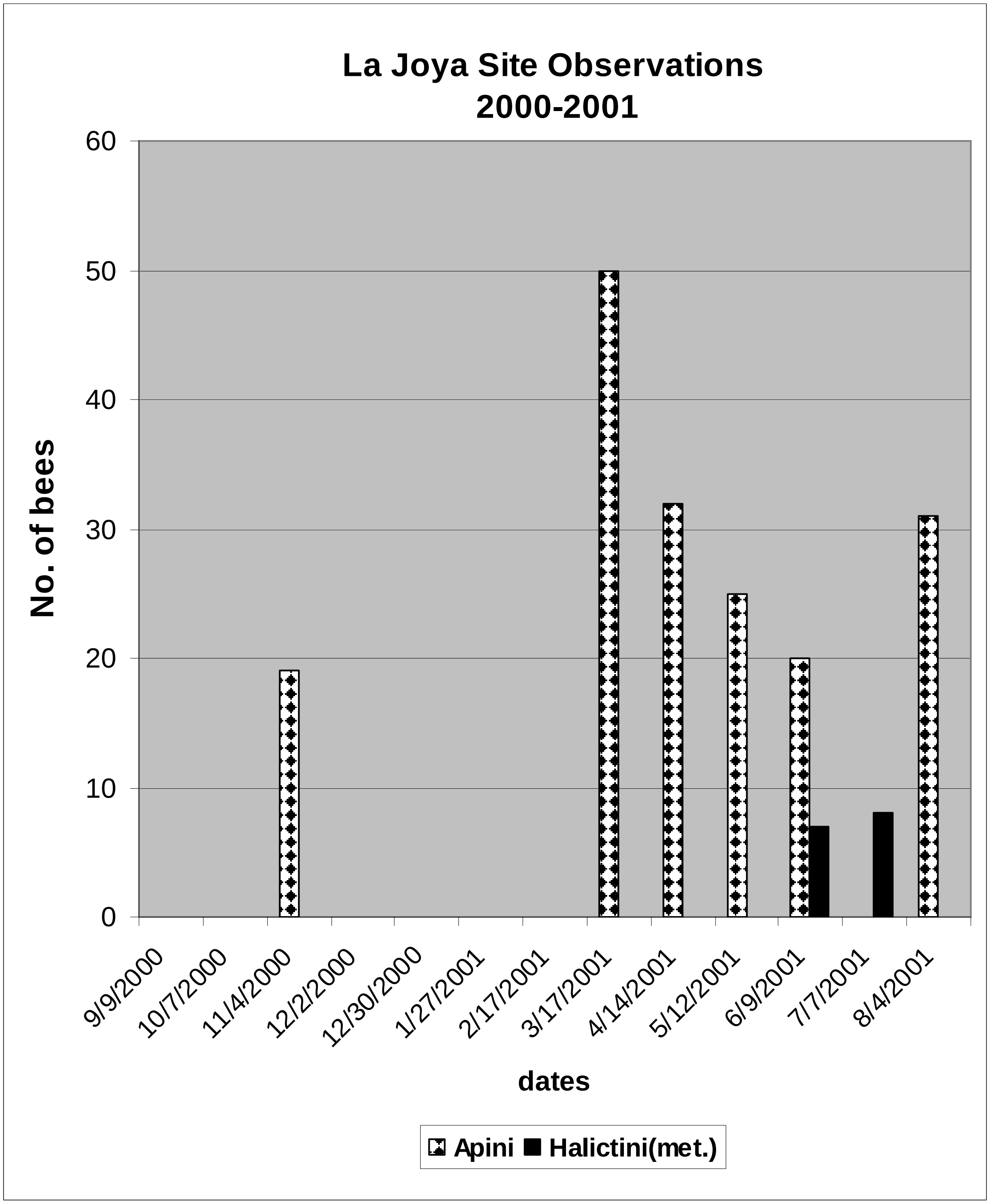

Figure 6B. La Joya Site Observations 2000-2001

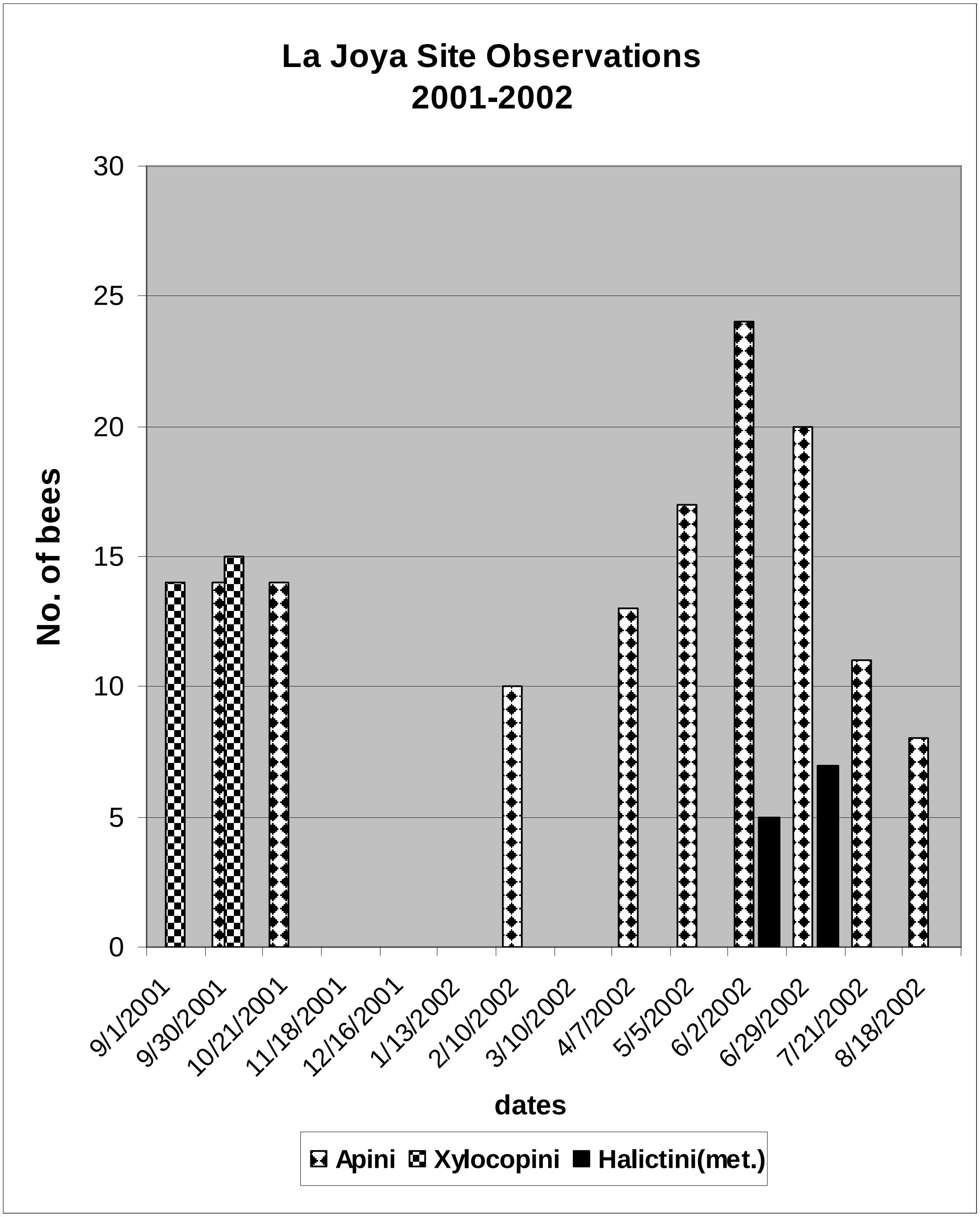

Figure 6C. La Joya Site Observations 2001-2002

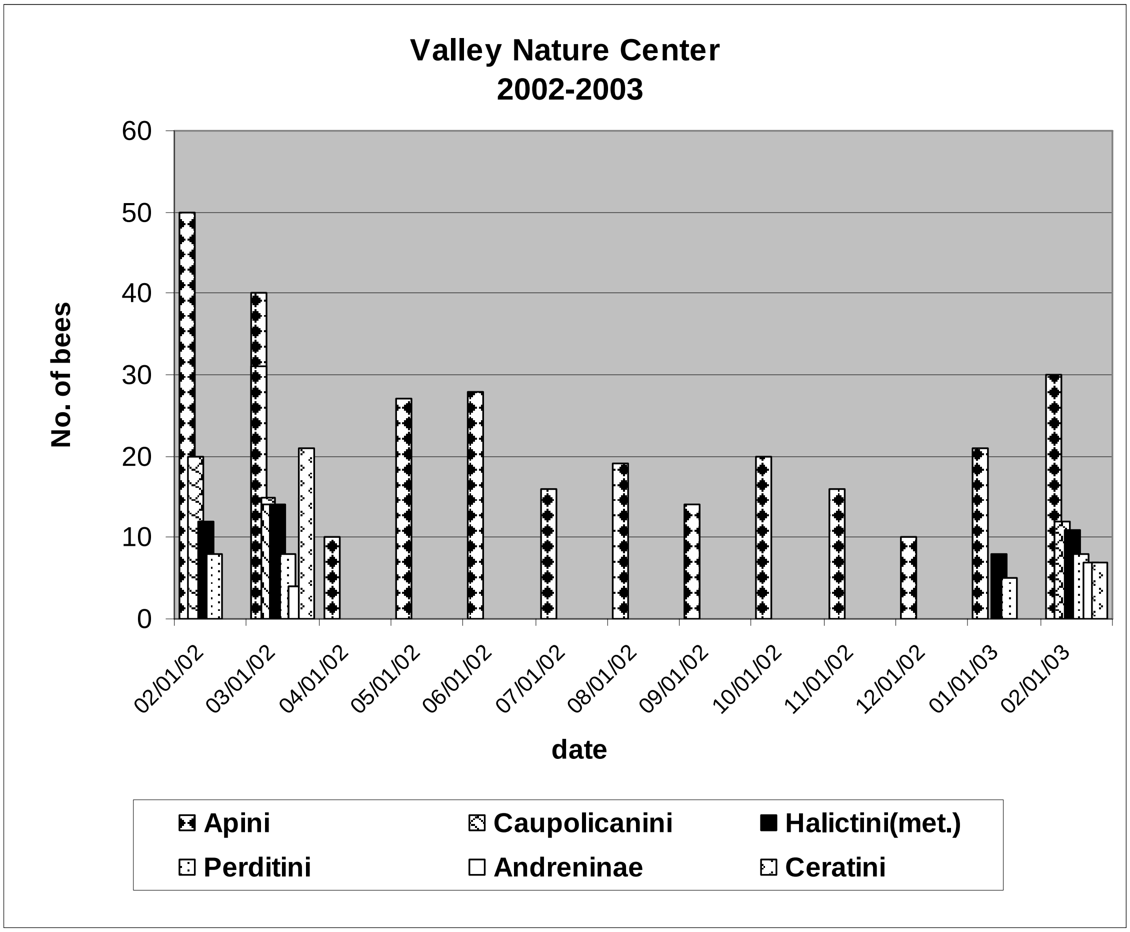

Figure 7A. Valley Nature Center Observations of Bee Numbers 2002-2003

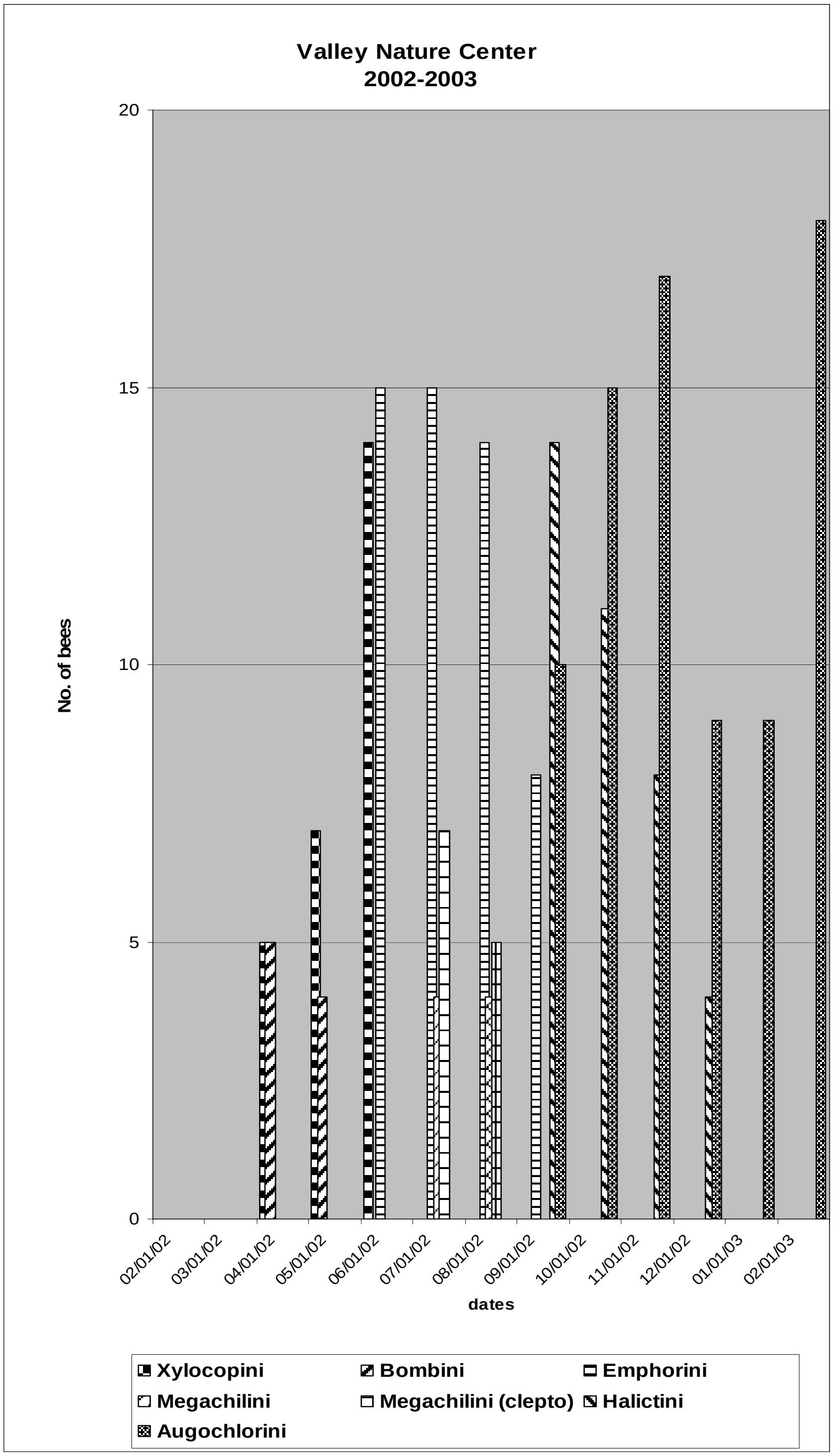

Figure 7B. Valley Nature Center Observations 2002-2003

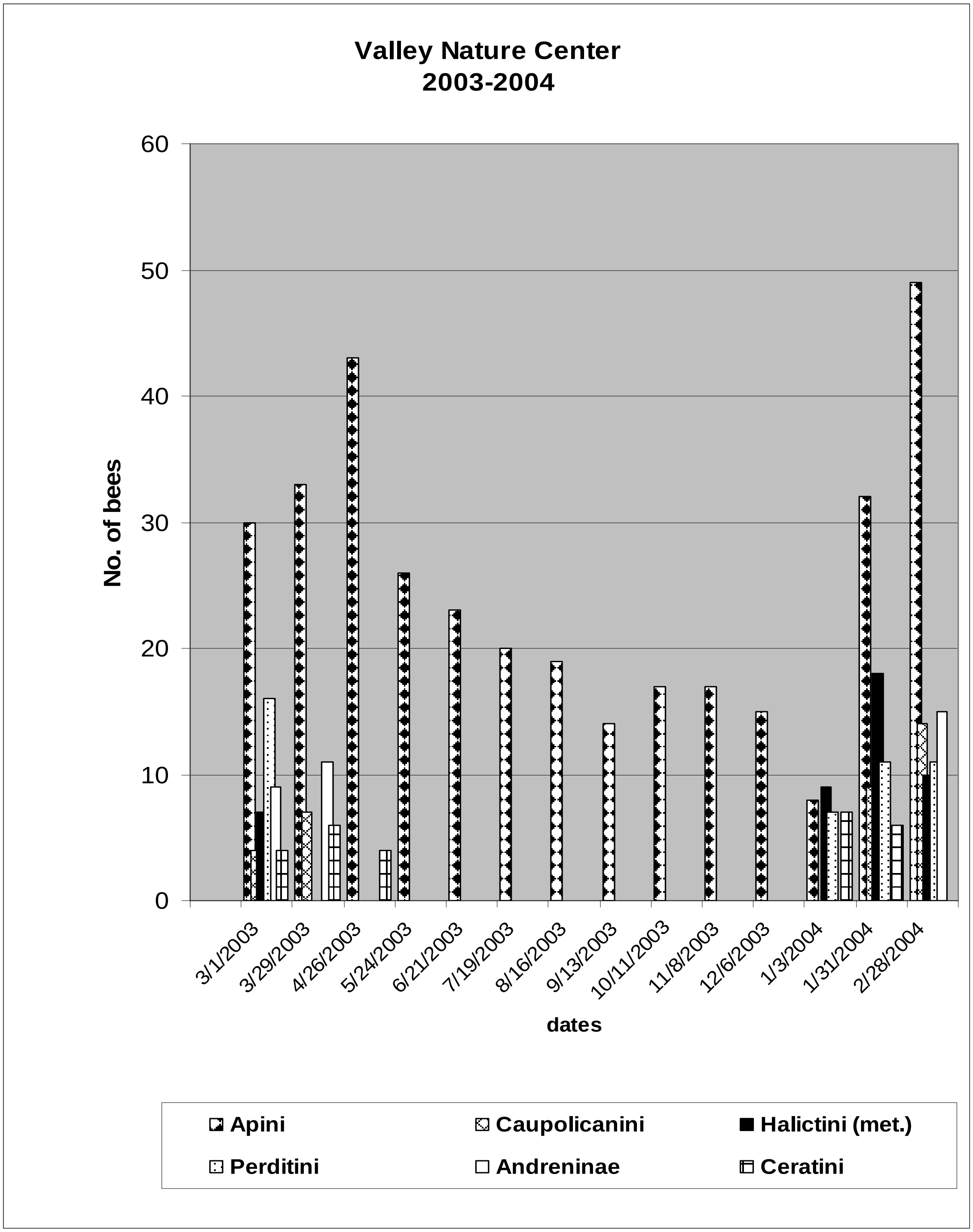

Figure 8A. Valley Nature Center Observations of Bee Numbers 2003-2004

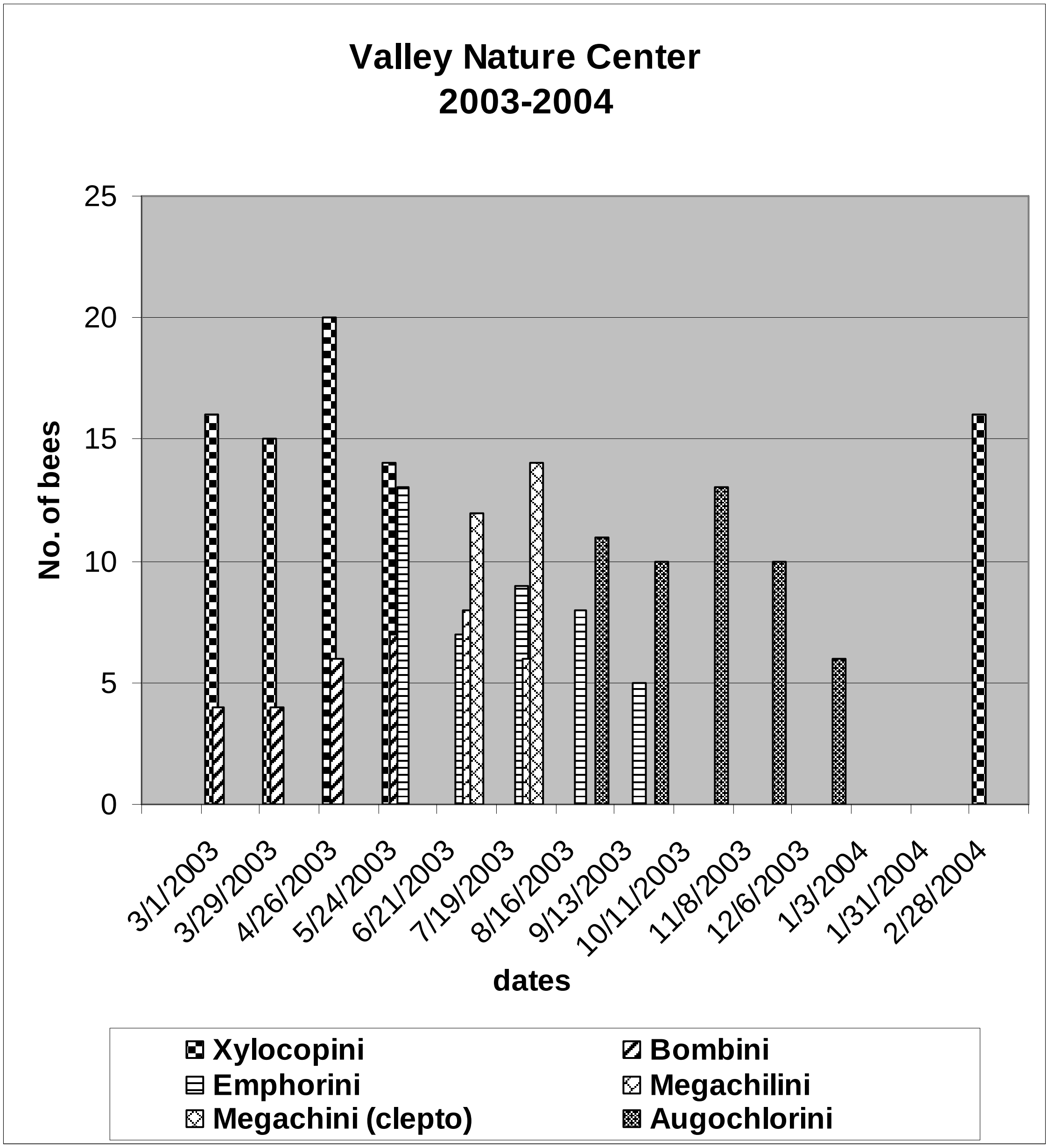

Figure 8B. Valley Nature Center Observations 2003-2004

In contrast, the Havana Tract had 50 plant species that provided nectar as the floral incentive (Table 2) while pollen was the floral reward of 36 species. Again, several species provided nectar as well as pollen resources for its floral rewards.

The Valley Nature Center had more than 300 plant species present and all the required water at its disposal. Although there were 29 species of plants that yielded nectar as the reward (Table 6) and only 10 species that provided a source of pollen as its floral incentive; but there were 123 species of vegetation that yielded both pollen and nectar from the floral resource.

When comparing the overall plant species diversity as compared to the bee species observed and/or collected, there were no distinctive trends except for the lack of floral diversity and bee diversity at the revegetated site. However, when comparing the plants by family to the bee, there were some definite trends. Overall, it appeared to be that Fabaceae and Verbenaceae were the two most important plant families in terms of pollinators present at each site.

Of the five bee families, Colletidae, Andrenidae, Halictidae, Megachilidae and Apidae expected to be present in south Texas, all five were found at the Valley Nature Center while the Havana Tract contained four of the five. The Havana Tract (native brush site) was lacking representation of the Colletidae family of bees. La Joya Tract only had two families of bees found during the three year study, Halictidae and Apidae.

Observational Data

Honey bees were the most common in all sites and at most times of the year (Fig. 5A, 5B, 5C, 6A, 6B, 6C, 7A, 7B, 8A and 8B). All the other genera (species) either fluctuated at sites or throughout the year.

What was ever common at any one site over the year may be related to nest sites or season variability during the study period. The raw data is included as Appendix B.

CHAPTER V

DISCUSSION

While the results varied between the three sites, there were surprising results particularly from the La Joya Tract. The Havana Tract yielded many genera and species of bees as well as the Valley Nature Center site. It was unexpected to see how depauperate the La Joya Tract was in its diversity.

Of the total documented numbers of genera and species found in Hidalgo County (Appendix B); it was an interesting comparison between the three study sites. Hidalgo County has 35 genera and 75 species of bees documented to date. The Havana Tract (native brush site) contained 13 genera and 17 species. This accounts for 40% of the genera and 23% of the species known to occur in Hidalgo Co. As a stark contrast, the La Joya Tract (revegetated site) had 3 genera and 4 species representing a mere 8.5% of the genera and 4% of the total species known to exist in this county. The Valley Nature Center (urban garden site) represented 34% of the genera and 16% of the species in Hidalgo Co. with its 12 genera and 13 species documented from this site.

The land practices used in revegetating the La Joya Tract involved replanting with native species. However, the floral rewards of the majority of those species were nectar and not pollen. Also, the revegetation of the entire La Joya Tract has not been completed and what has been done was performed piece meal. It has been a patchwork effect and coupled with the species planted adversely affected the biodiversity and abundance at this site. There were no unique genera or species observed or collected while there were several unique taxa found at the Havana Tract and Valley Nature Center site.

The La Joya Tract had an understory of *Urochloa maxima* (guineagrass). This is entire tract is divided up into parcels awaiting revegetation, the land is very disturbed which provides suitable habitat for guineagrass.

Another interesting aspect of the La Joya Tract; some of the bees observed and/or collected were from plants not involved in the replant. One in particular, *Clematis drummondii*, is invasive and prefers disturbed habitats. Many of the bees were found on this vine.

The Valley Nature Center has more than 300 species of vascular plants providing an abundance of nectar and pollen resources. These plants have ample water and the ideal growing conditions. The Valley Nature Center once had a severe problem with guineagrass. After approximately 5 years of steady, constant work; the Valley Nature Center is guineagrass free. As more time passed without the influence and cover of guineagrass, the understory began to flourish. It happened slowly at first but as more and more of the grass was eradicated, the native plant life took over. Some plants were installed and others came up on their own.

When evaluating the three sites for bees in common, only two genera were shared. *Apis mellifera* was abundant everywhere. It was collected and observed on *Parkinsonia aculeata* and *Acacia farnesiana.* These species are both in the Fabaceae family. *Parkinsonia aculeata* is referred to as a weed in the Rio Grande region especially in low, poorly drained areas (Fig. 9 and 10).

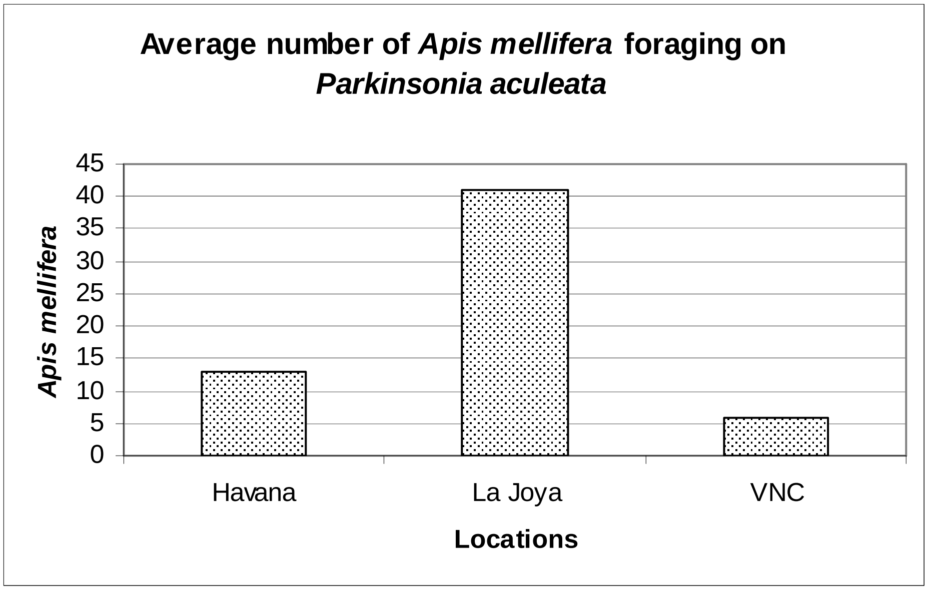

Figure 9. Average Number of *Apis mellifera* Foraging on *Parkinsonia aculeata*

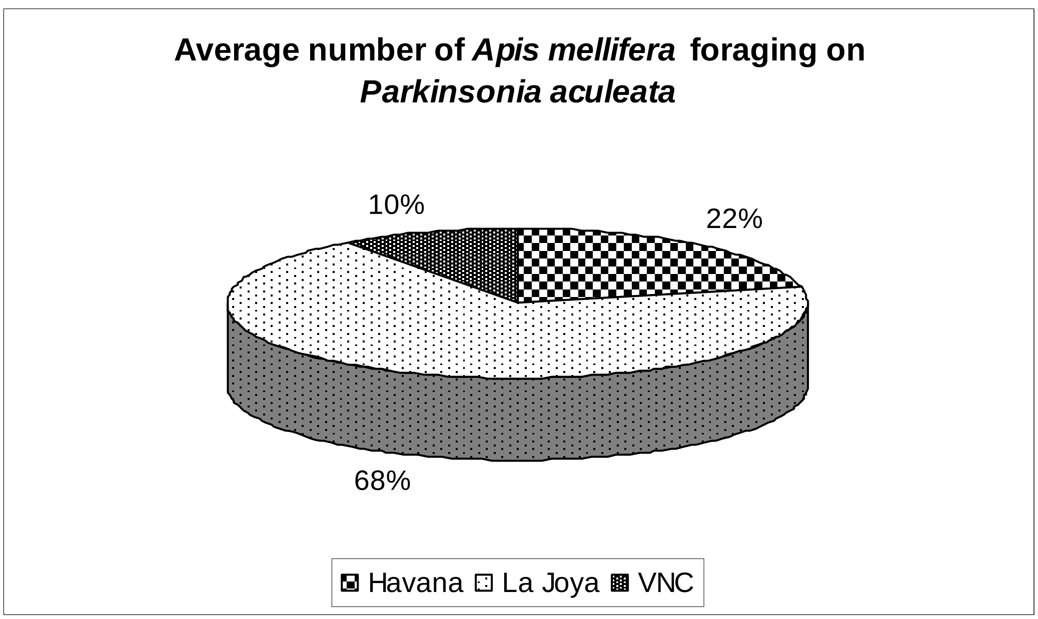

Figure 10. Average Number of *Apis mellifera* Foraging on *Parkinsonia aculeata* by Percentage

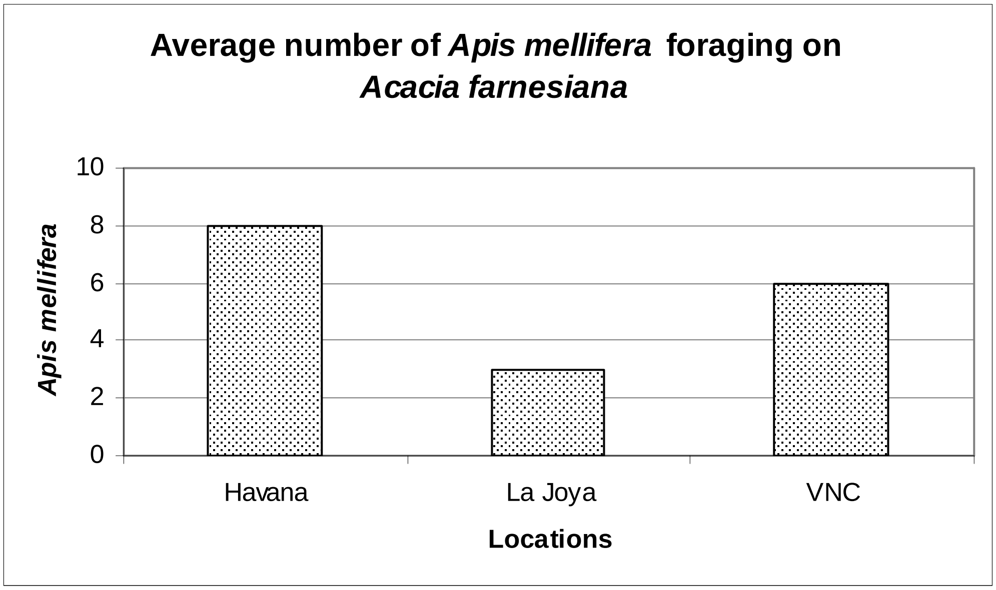

Figure 11. Average Number of *Apis mellifera* Foraging on *Acacia farnesiana*

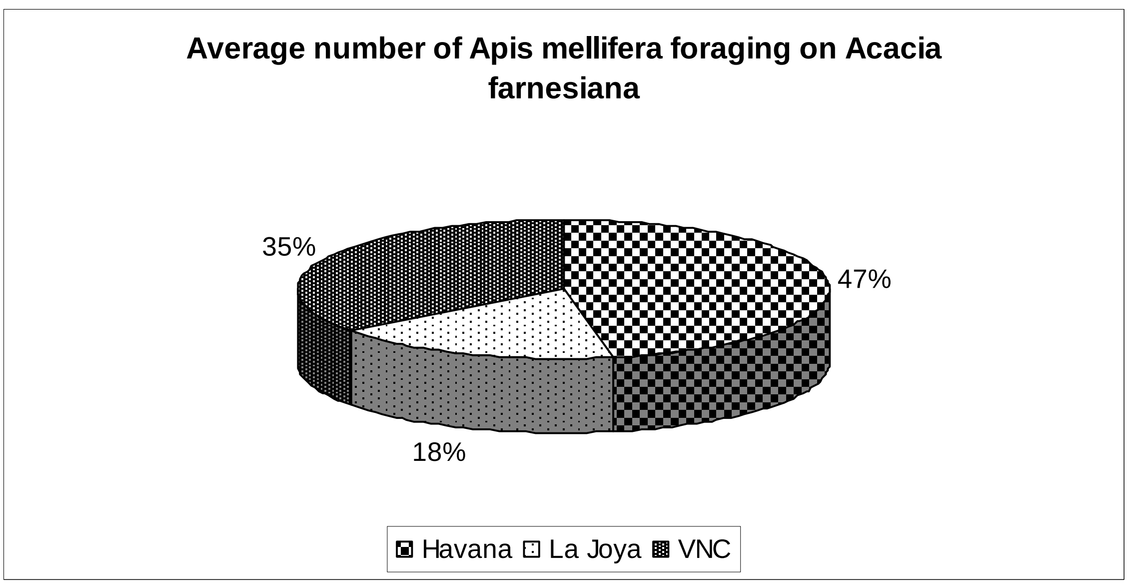

Figure 12. Average Number of *Apis mellifera* Foraging on *Acacia farnesiana* by Percentage

Acacia farnesiana is also widespread but not as common as *Parkinsonia aculeata* (Fig. 11 and 12). Although no seedlings of these taxa were used in the revegetation effort at the La Joya Tract, some of these were included and planted using the direct seeding method.

USFWS used two methods of revegetation originally. One, was the planting of small seedlings wrapped in biodegradable plant bands and second, they planted using viable seeds of native plants. There were 31,420 seeds of *A. farnesiana* planted while only 8,567 seeds of *P. aculeata*. *Acacia farnesiana* was represented by 25% of the total species planted by the direct seeding method while only 6% were *P. aculeata* (Table 8). The plant ecologist for the refuge determined the seedling methodology was more effective and preferred over the direct seeding protocol of revegetation.

Table 8. La Joya Direct Seed Mix history, a detailed list of the species and quantities used in the direct seeding methodology

Species	Quantity
Acacia rigidula	14,482
Acacia farnesiana	31,420
Acacia wrightii	639
Celtis laevigata	12,471
Cercidium texanum	3,131
Ehretia anacua	4,480
Fraxinus berlandieriana	3,092
Opuntia lindheimeri	16,220
Parkinsonia aculeata	8,567
Pithecellobium ebano	11,193
Pithecellobium pallens	1,722
Prosopis glandulosa	9,342
TOTAL	125,570

The other bee species in common to all three study sites was *Xylocopa mexicanorum*. It was observed and/or collected from *Cordia boissieri* at all three locations. This tree is in the Boraginaceae family. There were 82 seedlings planted at the La Joya Tract but only a small portion of them survived. This species has large white corollas, which entice larger bees, such as *Xylocopa*. *Cordia boissieri* contains both nectar and pollen rewards so it is ideal for *X. mexicanorum*. The results yield insight to the types of plants and the families best utilized in replanting and revegetating lands whether cleared or otherwise (Fig. 13 and 14).

USFWS revegetates approximately 800-1000 acres per year using the seedling method (Chris Best, USFWS Plant Ecologist, personal communication, 1999) It would be in the best interest of diversity and abundance to include more plants that have pollen as their floral reward. Also, more understory herbaceous plantings would enhance and increase the biodiversity of the area.

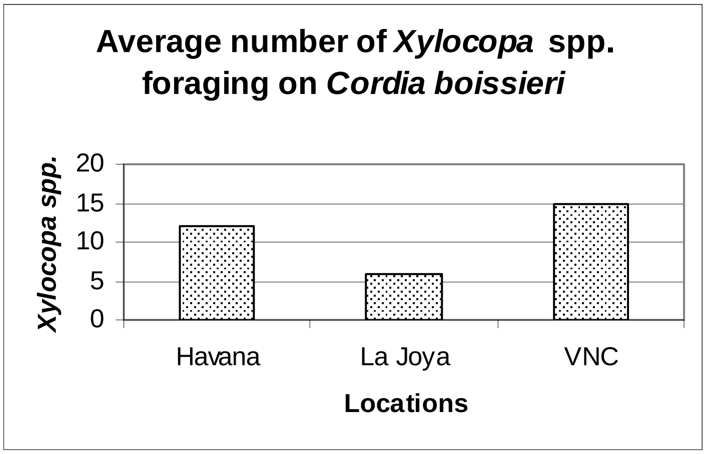

Figure 13. Average Number of *Xylocopa spp*. Foraging on *Cordia boissieri*

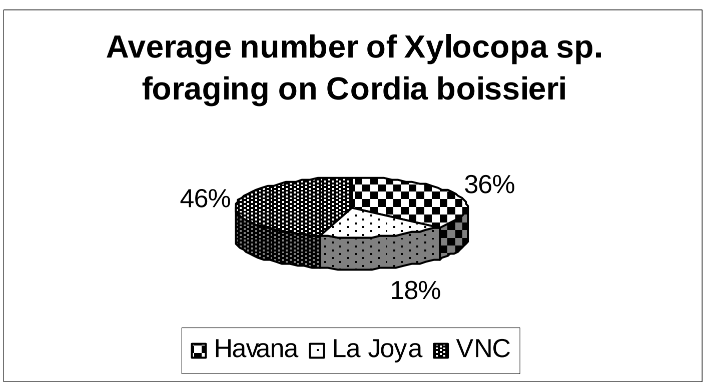

Figure 14. Average Number of *Xylocopa spp*. Foraging on *Cordia boissieri* as a Percentage

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

This study had several purposes for being conducted. It was to obtain baseline data of the pollinators frequenting different sites and different plants. It was also performed to evaluate the restoration methods of USFWS and to make any recommendations.

Replanting of the La Joya tract has been successful in terms of the reintroduction of native plant species into a cleared field. This could be referred to as phase 1 of the restoration efforts. Phase 2 would be to enhance and improve the already existing habitat.

Patches of herbaceous flowering understory plants should be added to any restoration project every 0.25 to 0.5 mile in order to enhance and encourage pollination along with its pollinators. This would lead to a greater diversity and abundance of solitary bees. Plants are a resource for herbivory and include pests, predators, prey and pollinators. Bees rely on the interactions of all of these along with the plants of interest.

Another factor to take into consideration is nesting requirements of bees. Many nest in dead wood. Girdling some of the tree limbs would provide suitable nest sites in a short period of time. The addition of brush piles would also promote solitary bee nesting.

After more time has elapsed from when the La Joya tract was revegetated, will allow for the trees to form a closed canopy that will shade out the guineagrass and slow its growth down. It also will have dead wood forming on its own along with the brush piles.

Fifteen years have passed since the revegetation occurred. Perhaps it is a science experiment in progress. More time may prove to be an ally for our solitary pollinators.

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APPENDIX A

Appendix Table A-1. Hidalgo county records (Dr. Jack Neff, 2005)

Family	Subfamily	Tribe	Genus	Subgenus	Species	Subspecies	Author
Andrenidae	Andreninae		*Andrena*	*Callandrena*	*accepta*		Viereck
Andrenidae	Andreninae		*Andrena*	*Parandrena*	*andrenoides*		(Cresson)
Andrenidae	Andreninae		*Andrena*	*Leucandrena*	*faceta*		LaBerge
Andrenidae	Andreninae		*Andrena*	*Scrapteropsis*	*flaminea*		LaBerge
Andrenidae	Andreninae		*Andrena*	*Callandrena*	*melliventris*		Cresson
Andrenidae	Oaxaeinae		*Protoxaea*	*Protoxaea*	*gloriosa*		(Fox)
Andrenidae	Panurginae	Calliopsini	*Calliopsis*	*Calliopsis*	*hondurasica*		Cockerell
Andrenidae	Panurginae	Perditini	*Macrotera*	*Cockerellula*	*lobata*		(Timberlake)
Andrenidae	Panurginae	Perditini	*Perdita*	*Hexaperdita*	*agasta*		Timberlake
Andrenidae	Panurginae	Perditini	*Perdita*	*Hexaperdita*	*ignota*	*Basalis*	Timberlake
Andrenidae	Panurginae	Perditini	*Perdita*	*Perdita*	*macswaini*		Timberlake
Andrenidae	Panurginae	Perditini	*Perdita*	*Perdita*	*martini*		Cockerell
Andrenidae	Panurginae	Perditini	*Perdita*	*Perdita*	*missionis*		Timberlake
Andrenidae	Panurginae	Perditini	*Perdita*	*Cockerellia*	*tricincta*		Timberlake
Andrenidae	Panurginae	Protandrenini	*Protandrena*	*Heterosarus*	*illinoiensis*		(Cresson)
Apidae	Apinae	Bombini	*Bombus*	*Fervidobombus*	*pensylvanicus*		(Degeer)
Apidae	Apinae	Ceratinini	*Ceratina*	*Calloceratina*	*cobaltina*		Cresson
Apidae	Apinae	Ceratinini	*Ceratina*	*Ceratinula*	*cockerelli*		Smith
Apidae	Apinae	Ceratinini	*Ceratina*	*Zadontomerus*	*diodonta*		Smith
Apidae	Apinae	Ceratinini	*Ceratina*	*Zadontomerus*	*texana*		Daly
Apidae	Apinae	Emphorini	*Diadasia*		*enevata*		(Cresson)
Apidae	Apinae	Emphorini	*Diadasia*		*ochracea*		(Cockerell)
Apidae	Apinae	Emphorini	*Diadasia*		*rinconis*	*Rinconis*	Cockerell
Apidae	Apinae	Emphorini	*Diadasia*		*tropicalis*		(Cockerell)
Apidae	Apinae	Ericrocidini	*Ericrocis*		*lata*		Cresson
Apidae	Apinae	Eucerini	*Melissodes*	*Tachymelissodes*	*opuntiella*		Cockerell
Apidae	Apinae	Eucerini	*Melissodes*	*Melissodes*	*tepaneca*		Cresson
Apidae	Apinae	Eucerini	*Melissodes*	*Eumelissodes*	*tristis*		Cockerell
Apidae	Apinae	Eucerini	*Svastra*	*Epimelissodes*	*grandissima*		(Cockerell)

Appendix Table A-1 (continued)

Family	Subfamily	Tribe	Genus	Subgenus	Species	Subspecies	Author
Apidae	Apinae	Eucerini	*Svastra*	*Epimelissodes*	*petulca*	*Suffusa*	(Cresson)
Apidae	Apinae	Exomalopsini	*Anthophorula*	*Anthophorisca*	*ignota*		(Timberlake)
Apidae	Apinae	Exomalopsini	*Exomalopsis*	*Exomalopsis*	*mellipes*		Cresson
Apidae	Apinae	Exomalopsini	*Exomalopsis*	*Exomalopsis*	*zexmeniae*		Cockerell
Apidae	Apinae	Protepeolini	*Leiopodus*		*singularis*		(Linsley and Michener)
Apidae	Nomadinae	Ammobatoidini	*Holcopasites*	*Holcopasites*	*calliopsidis*	*Carinatus*	(Linsley)
Apidae	Nomadinae	Nomadini	*Nomada*	*Micronomada*	*gutierreziae*		Cockerell
Apidae	Nomadinae	Nomadini	*Nomada*	*Micronomada*	*texana*		Cresson
Apidae	Nomadinae	Nomadini	*Nomada*	*Micronomada*	*vierecki*		Cockerell
Apidae	Xylocopinae	Xylocopini	*Xylocopa*	*Megaxylocopa*	*mexicanorum*		Cockerell
Apidae	Xylocopinae	Xylocopini	*Xylocopa*	*Schoenherria*	*micans*		Lepeletier
Apidae	Xylocopinae	Xylocopini	*Xylocopa*	*Stenoxylocopa*	*strandi*		Dusmet and Alonso, 1924
Apidae	Xylocopinae	Xylocopini	*Xylocopa*	*Notoxylocopa*	*tabaniformis*	Parkinsoniae	Cockerell
Colletidae	Colletinae	Colletini	*Colletes*		*cercidii*		Timberlake, 1951
Colletidae	Colletinae	Colletini	*Colletes*		*swenki*		Stephen
Colletidae	Colletinae	Colletini	*Colletes*		*texanus*	*texanus*	Cresson
Colletidae	Diphaglossinae	Caupolicanini	*Ptiloglossa*		*ST-1*		
Colletidae	Hylaeinae		*Hylaeus*	*Hylaeana*	*panamensis*		Michener
Halictidae	Halictinae	Augochlorini	*Augochlora*	*Oxystoglossella*	*aurifera*		Cockerell
Halictidae	Halictinae	Augochlorini	*Augochlora*	*Augochlora*	*azteca*		(Vachal)
Halictidae	Halictinae	Augochlorini	*Augochlorella*		*bracteata*		Ordway
Halictidae	Halictinae	Augochlorini	*Augochloropsis*	*Paraugochloropsis*	*metallica*	*metallica*	(Fabricius)
Halictidae	Halictinae	Halictini	*Agapostemon*	*Agapostemon*	*texanus*		Cresson
Halictidae	Halictinae	Halictini	*Agapostemon*	*Agapostemon*	*tyleri*		Cockerell
Halictidae	Halictinae	Halictini	*Halictus*	*Odontolictus*	*ligatus*		Say
Halictidae	Halictinae	Halictini	*Lasioglossum*	*Dialictus*	*hunteri*		(Crawford)
Halictidae	Halictinae	Halictini	*Lasioglossum*	*Dialictus*	*pictus*		(Crawford)
Halictidae	Halictinae	Halictini	*Lasioglossum*	*Dialictus*	*pruinosiformis*		(Crawford)
Halictidae	Halictinae	Halictini	*Lasioglossum*	*Lasioglossum*	*sisymbrii*		(Cockerell)
Halictidae	Halictinae	Halictini	*Lasioglossum*	*Dialictus*	*tegularis*		(Robertson)
Halictidae	Halictinae	Halictini	*Lasioglossum*	*Sphecodogastra*	*texanum*		(Cresson)

Appendix Table A-1 (continued)

Family	Subfamily	Tribe	Genus	Subgenus	Species	Subspecies	Author
Megachilidae	Megachilinae	Anthidiiini	*Stelis*	*Dolichostelis*	*perpulchra*		Crawford
Megachilidae	Megachilinae	Lithurgini	*Lithurgus*	*Lithurgopsis*	*littoralis*		Cockerell
Megachilidae	Megachilinae	Megachilini	*Ashmeadiella*	*Ashmeadiella*	*cactorum*	cactorum	(Cockerell)
Megachilidae	Megachilinae	Megachilini	*Ashmeadiella*	*Ashmeadiella*	*maxima*		Michener
Megachilidae	Megachilinae	Megachilini	*Coelioxys*	*Neocoelioxys*	*slossoni*	arenicola	Crawford
Megachilidae	Megachilinae	Megachilini	*Coelioxys*	*Synocoelioxys*	*texana*		Cresson
Megachilidae	Megachilinae	Megachilini	*Heriades*	*Neotrypetes*	*variolosa*	variolosa	(Cresson)
Megachilidae	Megachilinae	Megachilini	*Hoplitis*	*Robertsonella*	*"nemophilae"*		Ms. JLN
Megachilidae	Megachilinae	Megachilini	*Megachile*	*Sayapis*	*newberryae*		Cockerell
Megachilidae	Megachilinae	Megachilini	*Megachile*	*Chelostomoides*	*odontostoma*		Cockerell
Megachilidae	Megachilinae	Megachilini	*Megachile*	*Sayapis*	*policaris*		Say
Megachilidae	Megachilinae	Megachilini	*Megachile*	*Chelostomoides*	*prosopidis*		Cockerell
Megachilidae	Megachilinae	Megachilini	*Megachile*	*Chelostomoides*	*texensis*		Mitchell
Megachilidae	Megachilinae	Megachilini	*Megachile*	*Sayapis*	*zaptlana*		Cresson
Megachilidae	Megachilinae	Megachilini	*Osmia*	*Diceratosmia*	*subfasciata*	*subfasciata*	Cresson

APPENDIX B

Appendix Table B-1. Valley Nature Center observational data 2002-2004

Year	Date	Bee species	Nos. per 3 visits	Plant species
2002	Feb. 2	Apis mellifera	6, 8, 5	Acacia farnesiana
			3, 5, 4	Sophora secundiflora
			7, 9, 11	Buddleia sessifolia
		Lg. Brn/Tan	4, 4, 5	Lantana microcephala
			3, 2, 2	Buddleia sessifolia
		Med. Green metallic	2, 1, 2	Acacia berlandieri
			3, 2, 2	Buddleia sessifolia
		Sm. Brn/Blk.	2, 4, 2	Stachys drummondii
	Mar. 2	Apis mellifera	3, 2, 3	Leucophyllum frutescens
			5, 8, 7	Buddleia sessifolia
			4, 5, 3	Citharexylum berlandieri
		Lg. Brn/Tan	4, 4, 3	Guaiacum angustifolium
			2, 1, 1	Buddleia sessifolia
		Med. Brn	1, 1, 2	Buddleia sessifolia
		Med. Green metallic	3, 2, 2	Pluchea carolinensis
		Tiny Blk	4, 5, 6	Rivina humilis
		Sm. Brn/Blk.	3, 2, 3	Dicliptera vahaliana
	Mar. 30	Apis mellifera	3, 5, 7	Buddleia sessifolia
			4, 5, 2	Cordia boissieri
			2, 1, 2	Citharexylum berlandieri
		Tiny Blk	6, 8, 7	Rivina humilis
		Med. Brn	2, 1, 1	Buddleia sessifolia
		Lg. Brn/Tan	3, 5, 6	Pluchea carolinensis
		Med. Green metallic	2, 1, 3	Malvaviscus drummondii
			2, 3, 3	Lantana horrida
		Xylocopa sp.	2, 2, 1	Cordia boissieri
		Bombus sp.	1, 2, 2	Lantana macropoda
	Apr. 27	Apis mellifera	3, 4, 3	Citharexylum berlandieri
		Xylocopa sp.	2, 3, 2	Erythrina herbacea
		Bombus sp.	1, 2, 1	Malvaviscus drummondii
	May. 25	Apis mellifera	4, 8, 6	Erythrina herbacea
			3, 2, 4	Ehretia anacua
		Diadasia sp.	6, 4, 5	Helianthus annuus
		Xylocopa sp.	3, 4, 3	Cordia boissieri
			2, 1, 1	Malvaviscus drummondii
	June. 22	Apis mellifera	7, 4, 6	Lantana macropoda
			4, 4, 3	Ehretia anacua
		Diadasia sp.	5, 6, 4	Helianthus annuus
		Sm. Blk Pointy	1, 2, 1	Trixis inula
		Med. Blk Pointy	2, 2, 3	Trixis inula

Appendix Table B-1 (continued)

Year	Date	Bee species	Nos. per 3 visits	Plant species
	July. 20	Apis mellifera	4, 7, 5	Lantana macropoda
		Med. Blk Pointy	2, 1, 2	Trixis inula
		Sm. Blk Pointy	1, 1, 2	Trixis inula
		Diadasia sp.	4, 5, 5	Helianthus annuus
	Aug. 17	Apis mellifera	5, 8, 6	Plumbago scandens
		Diadasia sp.	3, 2, 3	Helianthus annuus
	Sept. 14	Apis mellifera	6, 4, 4	Abutilon hypoleucum
		Agapostemon melliventris	4, 4, 6	Plumbago scandens
		Green Halictids	3, 5, 2	Salvia coccinea
	Oct. 12	Apis mellifera	8, 5, 7	Salvia coccinea
		Agapostemon melliventris	2, 4, 5	Leucophyllum frutescens
		Green Halictids	5, 6, 4	Salvia misella
	Nov. 9	Apis mellifera	7, 4, 5	Leucophyllum frutescens
		Agapostemon melliventris	2, 3, 3	Plumbago scandens
		Green Halictids	4, 6, 7	Salvia misella
	Dec. 7	Apis mellifera	5, 3, 2	Salvia coccinea
		Agapostemon melliventris	2, 1, 1	Dicliptera vahaliana
		Green Halictids	4, 2, 3	Salvia misella
2003	Jan. 4	Apis mellifera	2, 2, 4	Phyla nodiflora
			4, 5, 4	Prosopis glandulosa
		Sm. Brn/Blk	1, 2, 2	Croton incanus
		Med. Green metallic	2, 2, 4	Trixis inula
		Green Halictids	3, 2, 4	Salvia misella
	Feb. 1	Apis mellifera	2, 3, 2	Buddleia sessifolia
			5, 4, 4	Solidago semipervirens
			3, 3, 4	Cercidium texana
		Sm. Brn/Blk	3, 2, 3	Aloyssia macrostachya
		Med. Green metallic	2, 4, 5	Solidago semipervirens
		Green Halictids	6, 7, 5	Acacia farnesiana
		Lg. Brn/Tan	4, 5, 3	Coursetia axillaris
		Tiny Blk	1, 2, 1	Rivina humilis
			1, 1, 1	Carlowrightia texana
		Med. Brn	3, 2, 2	Malvaviscus drummondii
	Mar. 1	Apis mellifera	4, 6, 7	Buddleia sessifolia
			2, 1, 1	Dicliptera vahaliana
			3, 4, 2	Eupatorium azureum
		Sm. Brn/Blk	4, 6, 6	Eupatorium azureum
		Med. Green metallic	3, 2, 2	Stachys drummondii
		Lg. Brn/Tan	1, 2, 1	Solanum erianthum
		Tiny Blk	2, 1, 1	Verbena halei
		Med. Brn	1, 2, 1	Citharexullum berlandieri
			1, 2, 2	Buddleia sessifolia
		Xylocopa sp.	2, 3, 3	Guaiacum angustifolium
			2, 2, 4	Buddleia sessifolia

Appendix Table B-1 (continued)

Year	Date	Bee species	Nos. per 3 visits	Plant species
		Bombus sp.	1, 1, 2	Leucophyllum frutescens
	Mar. 29	Apis mellifera	5, 4, 6	Buddleia sessifolia
			2, 2, 3	Solanum erianthum
			3, 4, 4	Citharexullum berlandieri
		Xylocopa sp.	2, 4, 3	Malvaviscus drummondii
			1, 3, 2	Cordia boissieri
		Bombus sp.	1, 1, 2	Citharexullum berlandieri
		Tiny Blk	1, 3, 2	Citharexullum berlandieri
		Med. Brn	3, 4, 4	Eupatorium azureum
		Lg. Brn/Tan	1, 3, 3	Buddleia sessifolia
	Apr. 26	Apis mellifera	5, 7, 4	Cordia boissieri
			2, 3, 5	Malvaviscus drummondii
			4, 6, 7	Ehretia anacua
		Xylocopa sp.	2, 3, 3	Erythrina herbacea
			3, 4, 5	Cordia boissieri
		Bombus sp.	2, 3, 1	Citharexullum berlandieri
		Tiny Blk	1, 2, 1	Salvia coccinea
	May. 24	Apis mellifera	4, 4, 3	Salvia ballotaeflora
			5, 6, 4	Ehretia anacua
		Diadasia sp.	3, 4, 6	Helianthus annuus
		Xylocopa sp.	5, 4, 5	Cordia boissieri
		Bombus sp.	3, 2, 2	Malvaviscus drummondii
	June. 21	Apis mellifera	3, 5, 4	Salvia ballotaeflora
			4, 3, 4	Ehretia anacua
		Diadasia sp.	2, 2, 3	Helianthus annuus
		Sm. Blk Pointy	2, 2, 4	Trixis inula
		Med. Blk Pointy	3, 5, 4	Trixis inula
	July. 19	Apis mellifera	4, 5, 6	Salvia coccinea
			2, 2, 1	Ehretia anacua
		Med. Blk Pointy	4, 5, 5	Trixis inula
		Sm. Blk Pointy	2, 3, 1	Trixis inula
		Diadasia sp.	4, 2, 3	Helianthus annuus
	Aug. 16	Apis mellifera	5, 8, 6	Salvia coccinea
		Diadasia sp.	2, 2, 4	Helianthus annuus
		Agapostemon melliventris	2, 4, 5	Lantana macropoda
	Sept.13	Apis mellifera	6, 5, 3	Opuntia lindheimerii
		Agapostemon melliventris	3, 5, 2	Lantana macropoda
		Green Halictids	2, 5, 4	Plumbago scandens
		Diadasia sp.	1, 2, 2	Helianthus annuus
	Oct. 11	Apis mellifera	5, 7, 5	Malvaviscus drummondii
		Agapostemon melliventris	4, 6, 3	Lantana microcephala
		Green Halictids	6, 4, 5	Abutilon hypoleucum
	Nov. 8	Apis mellifera	7, 6, 4	Malvaviscus drummondii
		Agapostemon melliventris	5, 2, 3	Salvia coccinea
		Green Halictids	4, 4, 6	Salvia misella

Appendix Table B-1 (continued)

Year	Date	Bee species	Nos. per 3 visits	Plant species
	Dec. 6	Apis mellifera	5, 6, 4	Salvia coccinea
		Agapostemon melliventris	2, 3, 2	Dicliptera vahaliana
		Green Halictids	6, 5, 7	Salvia misella
2004	Jan. 3	Apis mellifera	2, 3, 3	Croton incanus
		Sm. Brn/Blk	4, 2, 1	Salvia coccinea
		Med. Green metallic	2, 3, 4	Coursetia axillaris
		Green Halictids	5, 4, 6	Verbena halei
		Tiny Blk	3, 2, 2	Teucrium cubense
	Jan. 31	Apis mellifera	2, 2, 4	Siphonoglossa pilosella
			8, 7, 9	Buddleia sessifolia
		Sm. Brn/Blk	5, 4, 2	Salvia ballotaeflora
		Med. Green metallic	6, 7, 5	Buddleia sessifolia
		Green Halictids	4, 5, 5	Buddleia sessifolia
		Tiny Blk	2, 3, 1	Rivina humilis
		Lg. Brn/Tan	3, 2, 4	Salvia ballotaeflora
	Feb. 28	Apis mellifera	6, 8, 5	Parkinsonia aculeata
			2, 2, 3	Citharexulum berlandieri
			8, 9, 6	Buddleia sessifolia
		Sm. Brn/Blk	4, 3, 4	Salvia ballotaeflora
		Med. Green metallic	5, 3, 2	Acacia farnesiana
		Lg. Brn/Tan	4, 5, 5	Prosopis glandulosa
		Med. Brn	5, 4, 6	Buddleia sessifolia
		Xylocopa sp.	4, 2, 3	Parkinsonia aculeata
			3, 2, 2	Buddleia sessifolia

Lg. Brn/Tan = Ptiloglossa sp.
Med. Green metallic = Agapostemon sp
Med. Brn = Andrena sp.
Sm. Brn/Blk = Perdita sp.
Tiny Blk = Ceratina sp.
Sm. Blk Pointy = Megachile sp.
Med. Blk Pointy = Coelioxys sp.
Green Halictids = Augochloropsis sp.
Other bee species may have been present in these groupings but not determined by observations alone.

Appendix Table B-2. Havana and La Joya tracts observational data 1999-2002

Year	Date	Site	Bee species	Nos. per 3 visits	Plant species
1999	Sept. 11	La Joya	Apis mellifera	4, 2, 3	Aloyssia gratissima
				2, 2, 3	Cercidium texanum
			Xylocopa sp.	1, 1, 1	Cercidium texanum
		Havana	Apis mellifera	2, 3, 2	Lantana macropoda
				3, 4, 2	Acacia rigidula
				6, 4, 5	Parkinsonia aculeata
			"Green Halictids"	4, 5, 3	Acacia rigidula
	Oct. 9	La Joya	Apis mellifera	5, 7, 4	Baccharis salicifolia
				4, 5, 3	Mimosa pigra
		Havana		2, 3, 2	Lantana macropoda
	Nov. 6	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
	Dec. 4	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
2000	Jan. 2	La Joya	Apis mellifera	2, 3, 2	Cercidium texanum
		Havana	No bees		Nothing blooming
	Jan. 30	La Joya	Apis mellifera	3, 4, 2	Acacia farnesiana
				5, 8, 9	Cercidium texanum
		Havana	Apis mellifera	4, 5, 3	Acacia farnesiana
	Feb. 27	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
	Mar. 25	La Joya	Apis mellifera	10,12, 16	Parkinsonia aculeata
				23, 31, 37	Cercidium texanum
				15, 22, 26	Acacia rigidula
		Havana	Apis mellifera	20, 18, 15	Acacia rigidula
			Diadasia rinconis	27, 34, 41	Opuntia lindheimerii
			"Very small Blk/Brn"	2, 3, 2	Aphanostephus ramosissimus
			"Small - Med. Amber"	3, 2, 4	Acacia farnesiana
	Apr. 22	La Joya	Apis mellifera	12, 9, 10	Acacia rigidula
				5, 8, 11	Parkinsonia aculeata
				7, 11, 9	Leucaena pulverulenta
		Havana	Diadasia rinconis	75, 57, 62	Opuntia lindheimerii

Appendix Table B-2 (continued)

Year	Date	Site	Bee species	Nos. per 3 visits	Plant species
			"Very small Blk/Brn"	4, 3, 5	Teucrium cubense
	May. 20	La Joya	No bees		Nothing blooming
		Havana	Diadasia rinconis	15, 11, 18	Opuntia lindheimerii
2000	June. 17	La Joya	Apis mellifera	6, 4, 7	Clematis drummondii
		Havana	Apis mellifera	5, 8, 4	Opuntia leptocaulis
	July. 15	La Joya	Apis mellifera	5, 3, 8	Clematis drummondii
			"Med. Green metallic"	1, 2, 2	Clematis drummondii
		Havana	Bombus sp.	1, 3, 2	Acacia rigidula
			"Med. Green metallic"	3, 2, 3	Lantana macropoda
			"Green Halictids"	1, 2, 1	Lantana macropoda
	Aug. 12	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
	Sept. 9	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
	Oct. 7	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
	Nov. 4	La Joya	Apis mellifera	6, 5, 8	Clematis drummondii
		Havana	Apis mellifera	5, 3, 6	Leucophyllum frutescens
				2, 4, 5	Aloyssia gratissima
			"Green Halictids"	4, 2, 3	Aloyssia gratissima
			"Green Halictids"	3, 2, 2	Leucophyllum frutescens
			"Long Black"	5, 7, 4	Opuntia leptocaulis
	Dec. 2	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
	Dec. 30	La Joya	No bees		Nothing blooming
		Havana	No bees		Nothing blooming
2001	Jan. 27	La Joya	No Bees		Nothing blooming
		Havana	"Green Halictids"	7, 4, 5	Verbena bipinnatifida
	Feb. 17	La Joya	No bees		Nothing blooming

Appendix Table B-2 (continued)

Year	Date	Site	Bee species	Nos. per 3 visits	Plant species
		Havana	No bees		Nothing blooming
	Mar. 17	La Joya	Apis mellifera	8, 10, 16	Parkinsonia aculeata
				3, 4, 2	Cercidium texanum
				8, 11, 5	Acacia rigidula
		Havana	Apis mellifera	2, 4, 3	Verbena quadrangulata
			"Green Halictids"	3, 5, 3	Verbena quadrangulata
			"Very small blk/brn"	1, 2, 1	Teucrium cubense
			"Small - Med. Amber"	2, 3, 3	Acacia farnesiana
	Apr. 14	La Joya	Apis mellifera	4, 5, 8	Parkinsonia aculeata
				3, 7, 5	Leucaena pulverulenta
		Havana	Apis mellifera	2, 5, 4	Viguiera stenoloba
			"Very small blk/brn"	3, 5, 3	Viguiera stenoloba
			Diadasia rinconis	4, 7, 6	Opuntia lindheimerii
2001	May. 12	La Joya	Apis mellifera	6, 11, 8	Leucaena pulverulenta
		Havana	Diadasia rinconis	21, 18, 32	Opuntia lindheimerii
	June. 9	La Joya	"Med. Green Metallic"	2, 3, 2	Clematis drummondii
			Apis mellifera	6, 9, 5	Clematis drummondii
		Havana	"Med. Green Metallic"	3, 4, 2	Lantana macropoda
			Apis mellifera	4, 3, 3	Lantana macropoda
			Apis mellifera	3, 5, 6	Parkinsonia aculeata
	July. 7	La Joya	"Med. Green Metallic"	2, 3, 3	Clematis drummondii
		Havana	"Med. Green Metallic"	4, 2, 2	Acacia rigidula
			"Green Halictids"	3, 4, 3	Acacia wrightii
			Bombus sp.	1, 3, 2	Acacia wrightii
	Aug. 4	La Joya	Apis mellifera	10, 12, 9	Clematis drummondii
		Havana	Apis mellifera	6, 4, 5	Pithecellobium pallens
				10, 16, 14	Ehretia anacua
			Xylocopa sp.	2, 1, 2	Malvaviscus drummondii
	Sept. 1	La Joya	Xylocopa sp.	2, 2, 1	Clematis drummondii
				4, 2, 3	Cordia boissieri
		Havana	Xylocopa sp.	3, 5, 6	Cordia boissieri
				2, 3, 3	Malvaviscus drummondii

Appendix Table B-2 (continued)

Year	Date	Site	Bee species	Nos. per 3 visits	Plant species
			"Green Halictids"	3, 6, 4	Aloysia macrostachya
	Sept. 30	La Joya	Apis mellifera	5, 4, 5	Clematis drummondii
			Xylocopa sp.	2, 3, 2	Mimosa pigra
				2, 2, 4	Cordia boissieri
		Havana	Apis mellifera	6, 4, 4	Sarcostemma cynanchoides
			"Green Halictids"	3, 2, 4	Sarcostemma cynanchoides
			Xylocopa sp.	5, 3, 4	Cordia boissieri
				3, 2, 2	Parkinsonia aculeata
	Oct. 21	La Joya	Apis mellifera	3, 5, 6	Clematis drummondii
		Havana	Apis mellifera	6, 9, 7	Bumelia celastrina
			"Very small blk/brn"	5, 3, 4	Bumelia celastrina
			"Green Halictids"	4, 7, 5	Coursetia axillaris
	Nov. 18	La Joya	No bees		Few blooms
		Havana	Apis mellifera	5, 7, 4	Aloysia gratissima
				2, 3, 2	Aloysia macrostachya
			"Green Halictids"	5, 3, 4	Aloysia gratissima
				4, 2, 2	Aloysia macrostachya
				3, 5, 3	Coursetia axillaris
			"Long Black"	4, 3, 6	Opuntia leptocaulis
	Dec. 16	La Joya	No bees		Nothing blooming
		Havana	No bees		Few blooms
2002	Jan. 13	La Joya	No bees		Nothing blooming
		Havana	No bees		Few blooms
	Feb. 10	La Joya	Apis mellifera	3, 4, 3	Parkinsonia aculeata
		Havana	Apis mellifera	4, 2, 3	Parkinsonia aculeata
				5, 3, 4	Acacia farnesiana
	Mar. 10	La Joya	No bees		Few blooms
		Havana	No bees		Few blooms
	Apr. 7	La Joya	Apis mellifera	5, 4, 4	Leucaena pulverulenta
		Havana	Apis mellifera	3, 5, 2	Acacia rigidula
			Diadasia rinconis	26, 21, 29	Opuntia lindheimerii
			"Small - Med. Amber"	2, 2, 3	Viguiera stenoloba

Appendix Table B-2 (continued)

Year	Date	Site	Bee species	Nos. per 3 visits	Plant species
	May. 5	La Joya	Apis mellifera	6, 4, 7	Leucaena pulverulenta
		Havana	Diadasia rinconis	62, 54, 78	Opuntia lindheimerii
			Bombus sp.	3, 2, 3	Acacia rigidula
			"Very small blk/brn"	4, 5, 3	Acacia rigidula
	June. 2	La Joya	Apis mellifera	3, 2, 2	Leucaena pulverulenta
				4, 5, 8	Clematis drummondii
			"Med. Green Metallic"	1, 2, 2	Leucaena pulverulenta
		Havana	Apis mellifera	4, 7, 3	Acacia wrightii
			"Med. Green Metallic"	2, 3, 2	Leucophyllum frutescens
			Bombus sp.	2, 4, 2	Acacia rigidula
	June. 29	La Joya	Apis mellifera	7, 5, 8	Clematis drummondii
			"Med. Green Metallic"	1, 2, 4	Clematis drummondii
		Havana	Apis mellifera	3, 6, 4	Leucophyllum frutescens
				2, 4, 5	Acacia wrightii
			"Green Halictids"	2, 5, 3	Acacia wrightii
			"Med. Green Metallic"	3, 5, 6	Lantana macropoda
	July. 21	La Joya	Apis mellifera	4, 4, 3	Clematis drummondii
		Havana	"Green Halictids"	5, 5, 3	Lantana macropoda
			"Med. Green Metallic"	6, 7, 4	Acacia wrightii
	Aug. 18	La Joya	Apis mellifera	3, 2, 3	Clematis drummondii
		Havana	Apis mellifera	7, 5, 8	Sarcostemma cynanchoides
			"Green Halictids"	4, 5, 2	Lantana macropoda
			Xylocopa sp.	3, 4, 2	Cordia boissieri

Green Halictids = Augochlora, Augochloropsis
Very small blk/brn = Lasioglossum, Halictus, Exomalopsis
Small - Med. Amber = Andrena sp.
Med. Green metallic = Agapostemon
Long black = Lithurgus
Other bee species may have been in these groupings but not determined by observations alone.

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